Opinion on the Welfare of Animals during Transport

April 2019

Farm Animal Welfare Committee
Area 2D, Nobel House,
17 Smith Square, London SW1P 3JR

FAWC Opinions

FAWC Opinions are short reports to government[1] on contemporary topics relating to animal welfare. They are based on evidence and consultation with interested parties. They highlight particular concerns and indicate issues for further consideration by governments and others.

The Farm Animal Welfare Committee (FAWC) is an expert committee of the Department for Environment, Food and Rural Affairs in England and the Devolved Administrations in Northern Ireland, Scotland and Wales. More information about the Committee is available at https://www.gov.uk/government/groups/farm-animal-welfare-committee-fawc

Opinions published by the Farm Animal Welfare Committee

- Welfare of animals killed on-farm, 2018
- Sustainable agriculture and farm animal welfare, 2017
- The links between the health and wellbeing of farmers and farm animal welfare, 2017
- Free farrowing systems, 2015
- Calf nutrition, 2015
- CCTV in slaughterhouses, 2015
- Welfare of Farmed Fish at the Time of Killing, 2014
- Welfare of Farmed Fish, 2014
- Welfare of Farmed and Park Deer, 2013
- Welfare Implications of Breeding and Breeding Technologies in Commercial Livestock Agriculture, 2012
- Contingency Planning for Farm Animal Welfare in Disasters and Emergencies, 2012

[1] Where we refer to "Government" we are addressing the Department for Environment, Food and Rural Affairs in England, the Scottish and Welsh Governments, the Northern Ireland Assembly and other responsible Government Departments and Agencies.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAIRMAN'S LETTER TO SENIOR RESPONSIBLE OWNERS

Mr Alex Thomas (Director Animal and Plant Health and Welfare) – Defra
Mrs Sheila Voas (Chief Veterinary Officer) – Scottish Government
Professor Christianne Glossop (Chief Veterinary Officer) – Welsh Government

Dear Mr Thomas, Mrs Voas and Professor Glossop,

As you are aware, FAWC was asked for an opinion on the welfare of animals during transport and to undertake a review of the requirements to protect animal welfare during transport and to make recommendations.

Currently, legislation and its accompanying guidance is based on EU Regulation 1/2005. Whilst the majority of the EU Regulation 1/2005 still seems to meet with general recognition as to the validity of its welfare content, the lack of published and reviewed modern animal welfare research does raise some questions as to whether more could be done to improve travel welfare.

The scale of animal movements has changed, does change and will change again with the increasing size of transport vehicles and the changing patterns of demand of the owner, user or consumer. Every weekend, horses and ponies travel all over the country to compete as indeed do dogs and cats along with many other show species. Farm animals move within farms and holdings or to market and ultimately to a place of slaughter. The millions of animals that are transported and the potential welfare problems that these animals may experience warrants further understanding and to reduce the stress where feasibly possible, as all journeys are a stress.

Every enforced journey an animal undertakes has a stress attached to it. The justification for that journey and the minimisation of the stress should ultimately be the aim of the legislation.

One clear observation is that animals at the end of their lives are not always subject to the same degree of care and consideration as those either being reared, used or for breeding. In certain species the distances travelled to reach their final destination is markedly longer than at any other time of their lives or those of their non-breeding offspring e.g. so-called cull sows, spent hens, cull ewes, many horses and ponies.

Indeed, while there are improvements that can be made to the modes of transport the primary question as to whether there is a need for the movement to take place in the first place should become the focus of attention. Systems of rearing and keeping animals that require more and further live transport should be subject to question.

The trend for companies involved in consumer sale activities to stipulate as to where animals should be slaughtered means increased journey times with often the livestock carrying vehicles travelling past licensed abattoirs to reach the designated one favoured by the retailer.

The opinion does contain some specific conclusions and recommendations, but we have been mindful that there is more that can and should be done to review certain specific areas related to the transport of animals. We are aware that at the time of writing the reference has been to the EU Regulation 1/2005 and its relevance to the law as it applies in the various administrations within UK.

This FAWC opinion drew on expertise from around the UK; we visited Wales and Scotland to look at a number of operations that are integral to the transportation of animals. Also, in Scotland, we utilised a systematic review of the science, conducted by Scotland's Rural University College and the University of Edinburgh. This systematic review explored the main welfare concerns in the major species and major transport modes which has enabled us to highlight some important conclusions and recommendations. Finally, in England we held several stakeholder meetings and discussed the welfare of animals during transport. We have been most grateful for the considerable interest in this piece of work and specifically would wish to put on record our thanks to all of those who took the time to attend meetings and provide copious amounts of comment and evidence.

Peter C Jinman

Chairman FAWC

EXECUTIVE SUMMARY

Animals that are transported in connection with an economic activity and related operations are protected by the European Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97 (referred to hereafter as the 'EU Regulation 1/2005'). Animals are transported, within the UK and exported to the EU, for a number of different purposes including slaughter, production and breeding.

The UK government and Devolved Governments respect the welfare of all animals, and as part of their ongoing commitment to improve the welfare of all animals asked FAWC to review existing standards and their application, in order to make recommendations for improvements to the welfare of animals during transport. This FAWC opinion also informs development of the UK government's manifesto commitment, to take early steps to control the export of live farm animals for slaughter when the UK has left the EU.

In April 2018, the UK government, supported by Devolved Governments launched a Call for Evidence on controlling live exports for slaughter and to improve animal welfare during transport. In parallel, a systematic review on the welfare of animals during transport was commissioned by the UK government, using research funding owned by England, Scotland and Wales was conducted by Scotland's Rural University College (SRUC) and University of Edinburgh (UoE) following a competitive tendering process. Both the evidence and information from the Call for Evidence and the systematic review was made available to FAWC.

Based on the information received, FAWC conducted visits and met with stakeholders, and the outcomes of these have fed into the overall FAWC opinion.

FAWC have identified a number of welfare impacts which animals may experience when they are transported. Areas identified where the current framework could be improved, include improvement in training and education of transporters; better enforcement of existing requirements and dealing with non-compliance; the inclusion of all areas and types of transport and journey length within the regulation.

The SRUC systematic review, the Call for Evidence, and FAWC's own review highlighted a lack of objective scientific evidence in many areas pertinent to animal welfare during transport. However, FAWC have proposed a set of principles related to transport, which should be followed by all those involved with the transport of animals. These principles provide the basis for best practice for the transport of animals. The lack of a strong evidence base is concerning, considering the large numbers of animals that are transported and the considerable number of journeys being taken by animals at the direction of man Many farming systems and animal/ human interactions are dependent upon animals undertaking journeys, e.g. showing, sporting or companion events.

FAWC have provided recommendations and actions to maintain or improve animal welfare during transport, including species-specific recommendations, which should, be considered for incorporation in future regulations or guidance.

PART I: INTRODUCTION

1. The Farm Animal Welfare Council (FAWC)[2] was established in 1979 and its successor Committee was established in 2011. FAWC is an expert advisory group within the Department for Environment, Food and Rural Affairs (Defra) providing independent advice on animal welfare.
2. Defra and the Devolved Governments[3] consider that the welfare of animals may be further improved during transport and any improvements should be based on scientific evidence.
3. The terms of reference for this opinion are:
    a. To provide impartial, independent, timely, authoritative advice on what improvements can be made to the current regulatory regime for the welfare of animals during transport once the United Kingdom (UK) has left the European Union (EU) to Defra and the Devolved Administrations (DA) of Scotland, Wales and Northern Ireland.
    b. To cover specific animals that are included in the EU Regulation 1/2005 which are transported in relation to economic activity: cattle, sheep, pigs, goats, horses, poultry, cats, dogs, fur animals, laboratory animals, rabbits and other animals which may include fish, reptiles and amphibians.
    c. To explore species specific requirements during transport and provide advice on: space allowances, feed, water and rest periods, specific handling and vehicle requirements, loading, unloading and journey durations.
    d. To explore the welfare needs of the different species of animals, the information required should include optimal ranges of: temperature, relative humidity, noise, vibrations, and ammonia. These should be included to help to determine the maximum journey durations. All recommendations on requirements should ensure that the welfare of the transported animals is protected.
    e. To engage with relevant stakeholders to inform decisions on future improvements to the welfare of animals during transport, with the intention to review the current legal framework on welfare during transport.
4. The aim of this opinion is to provide advice to all the UK governments on animal welfare improvements that could, or should, be made, within the terms of reference as noted in paragraph 3. FAWC was tasked in looking at species outside of its usual remit and where there is evidence relating to those species this has been undertaken.
5. This opinion summarises the broad principles which should be applied when transporting animals to ensure that their welfare is protected.

[2] The Farm Animal Welfare Committee succeeded the Farm Animal Welfare Council; both use the same acronym, FAWC.
[3] Where we refer to "Government" we are addressing the Department for Environment, Food and Rural Affairs in England, the Scottish and Welsh Governments, the Northern Ireland Assembly and other responsible Government Departments and Agencies

FAWC's philosophy of approach

6. In 1965, the Brambell Committee, led by Professor Roger Brambell began the development of the 'Five Freedoms'. These Five Freedoms were designed to avoid unnecessary suffering and to promote good welfare for farm animals. The Five Freedoms remain an important tool, even after 54 years, as they still allow UK governments to make improvements to existing legislation to ensure the welfare of animals remains to the highest standards. The Five Freedoms are as follows:
    a. **Freedom from hunger and thirst**, by ready access to fresh water and a diet to maintain full health and vigour.
    b. **Freedom from discomfort**, by providing an appropriate environment including shelter and a comfortable resting area.
    c. **Freedom from pain, injury and disease**, by prevention or rapid diagnosis and treatment.
    d. **Freedom to express normal behaviour,** by providing sufficient space, proper facilities and company of the animal's own kind.
    e. **Freedom from fear and distress,** by ensuring conditions and treatment which avoid mental suffering.

7. The Five Freedoms have been the cornerstone of government and industry policy and are enshrined in the Codes of Recommendations for the Welfare of Livestock. In addition to the Five Freedoms, The Animal Welfare Act 2006 also ensures that the welfare needs of the animals are met and that the owner or keeper are responsible. The five welfare needs are:
    a. Need a suitable environment (place to live)
    b. Need a suitable diet
    c. Need to exhibit normal behaviour patterns
    d. Need to be housed with, or apart from, other animals (if applicable)
    e. Need to be protected from pain, injury, suffering and disease

8. For the first time, FAWC have included companion animals[4] and horses in their discussion and reporting. For the purpose of this opinion, "all animals" refers to companion, farm and horses unless otherwise stated. All animals are included in this opinion because the current EU Regulation, Council Regulation (EC) No 1/2005 covers all live vertebrate animals. Some sections are interchangeable, whilst other sections will focus primarily of farm animals, companion animals or horses. Whilst this report does cover all animals, it should be noted that majority of the work covered in this opinion and amongst the wider EU 1/2005 Regulation does tend to focus more on farm animals.

9. All animals are recognised as sentient beings within the EU Treaty of Amsterdam 1999. In addition, the Animal Welfare Act 2006 (England and Wales) and the Animal Health and

[4] For the purpose of this opinion, only dogs are covered in detail, unless stated elsewhere.

Welfare Act 2006 (Scotland) include a duty of care to provide for the needs of protected animals for which humans have permanent or temporary responsibility.

10. FAWC believe that its obligations include identifying and ensuring that certain serious harms never occur to any animal, and where possible to minimise any harm which might occur and endeavour to balance any harms to the animals affected against the benefits to humans and/or other animals. At a minimum, each individual animal should have a life that is worth living, and a growing proportion should have a good life.

11. There have been many attempts to define animal welfare. In FAWC's view, welfare encompasses both physical and mental health, and for all animals good welfare is largely determined on a daily basis by the skills of the stock people, owners, the system of husbandry, and the suitability of the animal genotype for the environment. From time to time, external factors can have an impact on welfare, for example; infectious disease epidemics, adverse weather conditions, global economics and geo-political influences. These circumstances often affect animal welfare in the short term and contingencies are necessary to minimise the severity and duration of poorer welfare.

12. Some pain and distress are unavoidable in all animal sectors even with current knowledge, husbandry and farming practises, but the goal should be to minimise their occurrence. Difficult ethical and practical decisions have to be made when dealing with suffering, sometimes by imposing a lesser act that may still cause short-term pain or distress but provide long-term relief for the individual or group. The long-term goal should be to eliminate the source of the problem through improved disease control, husbandry and breeding to avoid this lesser act.

13. When assessing any welfare problem, it is necessary to consider the extent of poor welfare, the intensity and duration of suffering, the number of animals involved, the alternatives available and the opportunities to promote wellbeing. Equally important is the ability to improve welfare immediately through existing sound husbandry and good stockmanship. Some day-to-day welfare challenges are seen across a range of species and farming systems, although some may be intrinsic to certain specific production systems.

14. To offer appropriate advice about the welfare of all animals, FAWC takes account of knowledge and the practical experience from scientists, veterinarians, farmers, Non-government organisations, charities and representatives. A broad-ranging approach is used in FAWC's advice, drawing on relevant views and attempting to take account of human interests with a concern to ensure that the animal's interests remain to the fore. When the knowledge base is poor, or when the application of evidence is inconclusive, the animal should be given the benefit of the doubt.

15. FAWC is made up of independent experts who rely on the latest scientific evidence from peer review publications, stakeholder engagements, industry input, related work within the field of

animal welfare and speaking with experts within the area. FAWC have advised government by providing reports, opinions and advice.

Scope and structure of this report

16. The UK government's manifesto commitment was to control the export of live animals for slaughter and to make improvements to the current regulatory regime.

17. To this end, on 10 April 2018, the UK government launched a Call for Evidence (CfE) supported by Scotland, Wales and Northern (**Appendix B**) on controlling live exports for slaughter and to improve animal welfare during transport after the UK leaves the EU. The CfE was held for six weeks and closed on the 22 May 2018.

18. Live exports are defined in this FAWC opinion as any animal that is transported to a country that is different to their original country of origin both within the EU and outside of it.

19. The number of responses to the CfE was 366, the evidence submitted by participants was passed on to FAWC. FAWC established a "transport working group" in July 2018 (**Appendix E**), engaged with a number of stakeholders in England, Scotland, Wales and NI who participated in the CfE (**Appendix D**) and undertook visits to key areas of interest.

20. In parallel, the UK government and Devolved Governments agreed to commission a systematic review on the welfare of animals during transport using jointly held research monies. This was carried out by Scotland's Rural University College (SRUC) and University of Edinburgh (UoE). The report of the systematic review was presented as evidence to FAWC.

21. This opinion combines scientific evidence from the Call for Evidence[5], systematic review (**Appendix A**), expert opinions through stakeholder engagement and visits, the European Food Safety Authority (EFSA) report on Scientific Opinion Concerning the Welfare of Animals during Transport[6] and the Report from the Commission to the European Parliament and the Council on the impact of Council Regulation (EC) No 1/2005 on the protection of animals during transport[7].

---

[5]Defra CfE: https://consult.defra.gov.uk/animal-health-and-welfare/live-exports-and-improving-welfare-in-transport/

[6] EFSA Journal 2011; 9(1):1966. https://efsa.onlinelibrary.wiley.com/doi/epdf/10.2903/j.efsa.2011.1966

[7] Commission Report 2011. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0700&from=EN

22. Throughout this report, transportation refers to the whole process including: planning, loading, actual travelling, rest stop(s), break(s), unloading, and handling and management at the end destination.

Devolution and international matters

23. Animal welfare regulation is a devolved matter in the UK and currently subject to EU regulation and international agreements which are due to be rolled over to UK legislation when the UK leaves the EU.

Ethical considerations

24. Animals have value, independent of their usefulness to humans, and should not be regarded as purely economic goods. Live animals transported as part of human activity must have their welfare needs met.

25. The transport process has the potential to negatively impact an animal's welfare. During a journey, for example, normal behaviours are restricted, and unavoidable vehicle motion may cause distress. However, transport may also bring a positive welfare impact, for example by delivery of the animal to a 'higher-quality' environment.

26. Transport encompasses a wide range of journey types, from simple unscrutinised journeys, to multiple stage and multiple modal journeys, which are normally more closely monitored and regulated.

27. One or more people along the transport supply chain will be responsible for an animal's welfare during the transport process, and this elongated chain of responsibilities may continue outside the jurisdiction of the place of origin.

28. Currently, the original breeder or rearer, in becoming a vendor, may have limited knowledge of an animal's final destination and likely future welfare. However, integrated companies can have oversight of the whole transport process, final destination and welfare. Legal responsibility for an animal's welfare during a multiple stage journey may be divided. However, before deciding to sell or transport an animal, there is an ethical responsibility to take reasonable active steps to check that that the animal(s) welfare will be protected up to, and at its final destination.

Limitations to this report

29. FAWC will make recommendations as to what improvements can be made to the EC 1/2005 Regulation based on scientific evidence where available on evidence presented and expert opinion and the result of the working group undertaking visits.

30. FAWC also acknowledges that not all of the species have been covered in this FAWC opinion and recommend that other species should be considered in a follow up opinion on the transport of animals that are not covered i.e. fish, cats and other animals.

PART 2: BACKGROUND

Transport of animals

31. All transport movements are stressful for animals, with a number of contributing factors that influence this, including catching, moving/ herding, loading, unloading (either individually directly or in modules), the actual journey, driver quality and access to food, water and rest.

32. Transportation has always been an inherent part of livestock farming. Today, animals are transported globally for the purposes of rearing, production, breeding, slaughter or entertainment.

33. The economic purposes for which animals are moved include: meat, dairy and fibre production; matching of regional and national supply; sport; recreation and entertainment; and genetic improvement and gene pool protection.

34. Although the same legal requirements apply, as a matter of commercial practice animals of high economic value are generally transported under better welfare conditions due to their higher value, (e.g. breeding sows or racing horses). In contrast, animals of lower economic value (e.g. older 'spent' animals at the end of their use being transported for slaughter) may not receive transportation that accommodates all of their basic needs.

35. For the purpose of this FAWC opinion and <u>not defined as stated in the 1/2005 Regulation</u>; **Journey time** is referred to as the journey, where the vehicle is moving and does not take into account the loading, unloading or rest time. **Overall journey** time takes into account the entire journey including: loading (starting from 1st animal on), unloading (ending with the last animal off) and rest times (as shown in **Figure 1**). Throughout the FAWC opinion, these terms will be used to define the type of journey. Note the 1/2005 Regulation definition of journey time in paragraph 44.

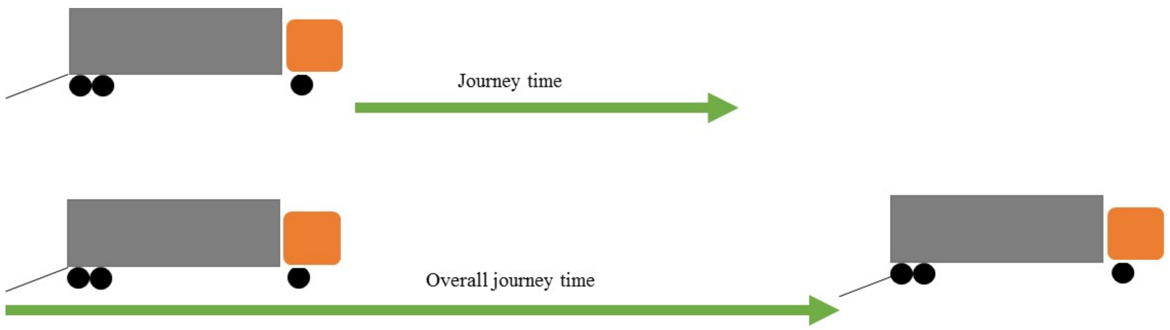


Figure 1 A schematic diagram of the maximum journey times and journey times.

Current legal framework to protect animal welfare

36. The EU Regulation, Council Regulation (EC) No 1/2005 came into force on 5 January 2007 and applies to all Member States of the EU. Enforcement, penalties and derogations of the Regulation 1/2005 are provided by national legislation:

a. England - The Welfare of Animals (Transport) (England) Order 2006;
b. Wales – The Welfare of Animals (Transport) (Wales) Order 2007;
c. Scotland – The Welfare of Animals (Transport) (Scotland) Regulations 2006 and The Welfare of Animals (Transport) (Scotland) Amendment Regulations 2009;
d. Northern Ireland – The Welfare of Animals (Transport) Regulations (Northern Ireland) 2006 and The Welfare of Animals (Transport) (Amendment) Regulations (Northern Ireland) 2007.

37. The EU Regulation 1/2005 covers all live vertebrate animals (mammals, birds, reptiles, amphibians and fish) that are transported for economic activity[8] and related operations but it does not cover the following[9]:
    a. movements not in connection with an economic activity;
    b. non-vertebrate animals;
    c. to or from veterinary practices under the advice of a veterinarian; and
    d. farmers moving their own animals less than 50 km

38. Whilst this list is not exclusive, those involved in transporting as part of an economic activity include; farmers, livestock hauliers, those who move domestic equines in connection with professional riding, livery and stabling, those involved in commercial pet breeding or racing (e.g. dog racing), those moving animals used in films, zoos, leisure parks charities, research facilities, pet couriers, breed societies (conservation breeders) and equine hauliers.

39. Animals can be transported via road, rail, sea and air, during which there are specific conditions which must be met. The EU Regulation 1/2005 sets out general requirements for each of the different types of transport, which include inspections and approvals and vehicle and transporter construction to avoid injury to the animals. In addition to Council Regulation (EC) No 1/2005 the International Air Transport Association's, Live Animal Regulations (IATA LAR) provides additional requirements for animal protection during flights.

40. Anyone transporting live vertebrate animals for commercial purposes on journeys over 65km must hold the correct transport documentation for their journey, which includes; Transporter Authorisation, Certificates of Competence, and where necessary, Vehicle Approval Certificates and Journey Logs.

41. There are two types of transporter authorisation;
    a. **Type 1** transporter authorisation is valid for journeys over 65km and up to a maximum of 8 hours in journey time, and;
    b. **Type 2** is valid for all journeys up to and over 8 hours in journey time. Anyone wishing to transport animals in other EU countries, on long journeys (exceeding 8

[8] Paragraph 12 in the EU Regulation states: "Transport for commercial purposes is not limited to transport where an immediate exchange of money, goods or services takes place. Transport for commercial purposes includes, in particular, transport which directly or indirectly involves or aims at a financial gain".
[9] The Welfare of Animals (Transport) (England) Order 2006, Part 2, para 4 does cover these provisions.

hours) requires a Type 2 transporter authorisation, driver/attendant certificate of competence (if transporting the appropriate species) and the vehicle must hold a valid vehicle approval certificate.

42. In addition to Transporter Authorisation, drivers transporting cattle, sheep, pigs, goats, horses and poultry and those handling these animals during transport (referred to as attendants), require suitable training and must hold a Certificate of Competence. There are two types of Certificates of Competence;
    a. **Short journey (obtained by a theory test)**; which is valid for journeys over 65km and up to a maximum of hours in journey time and consists of a theory test and:
    b. **Long journey (obtained by a theory and practical test)**; which is valid for journeys up to and over 8 hours in journey time. This consists of a theory and a practical test.

43. Once obtained, a Certificate of Competence is valid for life (unless revoked) and there is no on-going renewal training.

44. Commercial heavy goods vehicle (HGV) drivers, require 35 hours of training every 5 years (CPC Training). There is no requirement to include animal welfare and handling as part of ongoing CPC Training.

45. Road vehicles and containers used for transporting animals on long journeys, in excess of 8 hours must be inspected for compliance with the 1/2005 Regulation and hold a valid vehicle approval certificate. The Welfare of Animals (Transport) (England) Order 2006 (WATO) provides a derogation to this requirement if transporting within the UK (only) over 8 hours and up to 12 hours in journey time.

46. When transporting cattle, sheep, pigs, goats and unregistered horses on journeys over 8 hours outside the UK, to third countries and the EU, a journey log is required. Journey time is calculated from the time the first animal is loaded onto the vehicle at the initial premises of origin, until the last animal is unloaded at the destination premises. A journey ends when the last animal is unloaded from the vehicle at the place of destination and is either accommodated for at least 48 hours or slaughtered.

47. The transporter must complete and submit section 1 of the journey log to the Animal and Plant Health Agency (APHA) for approval prior to the start of a long journey to another Member State or third country. This is to ensure the planned journey is in compliance with the Regulation.

48. The journey log includes; place of departure, place of destination, rest stops, space allowance, journey time and details of the transporter and driver. Other sections of the journey log must be completed throughout the journey by the transporter. Upon completion of the journey, the journey log is returned to APHA, where it may be subject to a compliance audit.

Volumes of movement

49. Trade in animal exports and imports are monitored by the Trade Control and Expert System (TRACES) which records the number of animals exported and imported from around the EU.

50. The number of animals exported from the UK to EU Member States is provided in **Table 1**[10], which shows the volume of trade in live exports for slaughter, production and breeding to the EU during 2016. This indicates the scale of the trade for the whole of the UK.

51. The majority of live animal exports in the UK are to the RoI as shown in **Table 1**. This table shows that very few animals were transported to the EU in 2016. The majority of the animals that were exported to the EU were poultry, with the majority of these going to the Netherlands.

52. The number of animals imported from EU Member States to the UK is provided in **Table 2.**[11] This shows the volume of trade in live imports for slaughter, production and breeding from the EU during 2016. This indicates the scale of the trade for the whole of the UK.

[10] Source: published data from TRACES, available at https://ec.europa.eu/food/animals/traces/facts-figures_en 2016 report: https://ec.europa.eu/food/animals/traces/facts-figures_en
[11] Source: published data from TRACES, available at https://ec.europa.eu/food/animals/traces/facts-figures_en 2016 report: https://ec.europa.eu/food/animals/traces/facts-figures_en

Table 1 The volume of trade in live animals for slaughter, fattening[12] and breeding from the UK to Republic of Ireland and the rest of the EU in 2016.[13]

Purpose	Volumes of live exports to:	Livestock species				
		Sheep	Cattle	Pigs	Poultry	Horses
Slaughter	EU	385,099	10,464	8,916	-	-
	RoI	380,909	10,464	8,916	-	-
	EU excl. RoI	**4,190**	**-**	**-**	**-**	**-**
Fattening	EU	93,778	25,433	2	13,291,141	-
	RoI	50,529	888	-	3,861,919	-
	EU excl. RoI	**43,249**	**24,545**	**2**	**9,429,222**	**-**
Breeding	EU	4,978	6,453	1,695	3,689,957	468
	RoI	1,334	2,104	18	1,075,223	-
	EU excl. RoI	**3,644**	**4,349**	**1,677**	**2,614,734**	**468**
Other purposes (a)	EU	-	-	-	-	16,461
	RoI	-	-	-	-	-
	EU excl. RoI	**-**	**-**	**-**	**-**	**16,461**
Total live exports to EU (excl. RoI)		**51,083**	**28,894**	**1,679**	**12,043,956**	**468**

(a) Other purposes: includes registered horses and horses exported for unknown reasons which could include slaughter as well as e.g. recreational training purposes.

[12] Fattening refers to production, including rearing and finishing for slaughter.
[13] Traces - https://ec.europa.eu/food/sites/food/files/animals/docs/ahsc_report_2016_en.pdf

Table 2 The volume of trade in live animals for slaughter, fattening and breeding to the UK from the rest of the EU in 2016.

Purpose	Volumes of live imports from	Livestock species				
		Sheep	Cattle	Pigs	Poultry	Horses
Slaughter	EU	552	8,664	356,746		-
	RoI	236	8,664	356,746		-
	EU excl. RoI	**316**	**-**	**-**	**-**	**-**
Fattening	EU	1,749	10,367	99,192		-
	RoI	1,749	9,100	99,192		-
	EU excl. RoI	**-**	**1,267**	**-**		**-**
Breeding	EU	813	25,535	3,949	16,102,421	103
	RoI	109	10,147	2,276	-	-
	EU excl. RoI	**704**	**15,388**	**1,673**	**16,102,421**	**103**
Other purposes [(a)]	EU		2	-	3,878,975	7,644
	RoI		-	-	3,199,700	-
	EU excl. RoI	**-**	**2**	**-**	**679,275**	**7,644**
Total live imports from EU (excl. RoI		**1,020**	**15,390**	**1,673**	**16,781,696**	**7,747**

(a) Other purposes: includes registered horses and horses exported for unknown reasons which could include slaughter as well as e.g. recreational training purposes.

Internal movements

53. The majority of animals that are transported, are moved within the UK as internal movements. The actual number of internal movements are difficult to estimate as not all of these journeys are recorded.

54. **Table 3** and **Figure 2** show the numbers of animals that were slaughtered in 2017, separated into England and Wales, Scotland and NI. Over 2 million cattle, 14 million sheep and 10 million pigs were slaughtered, and effectively all of these animals would have been transported to the slaughter house.

55. The number of internal animal movements between GB and NI are presented below. As shown, the number of animals being transported between NI and GB is quite low. The high number of pigs being transported from NI to GB indicates the lack of suitable facilities to slaughter adult pigs in NI, and currently these journeys are carried out because of a lack of alternative options.

56. Many animals are transported to and from Scottish or other GB islands. Often, there are no facilities to slaughter or grow these animals on the islands, therefore these animals currently require to be transported to mainland GB (see **Table 4** for the durations of these journeys).

Table 3 Number of animals slaughtered in the UK in 2017 [14]

	Livestock species (in 10 thousand head)			
	Poultry	**Cattle**	**Sheep**	**Pigs**
England & Wales	92,225	185	1,328	874
Scotland	**	46	114	25
NI	**	45	45	167
UK Total	**110,422**	**275**	**1,487**	**1,066**

** Breakdown not available in public domain

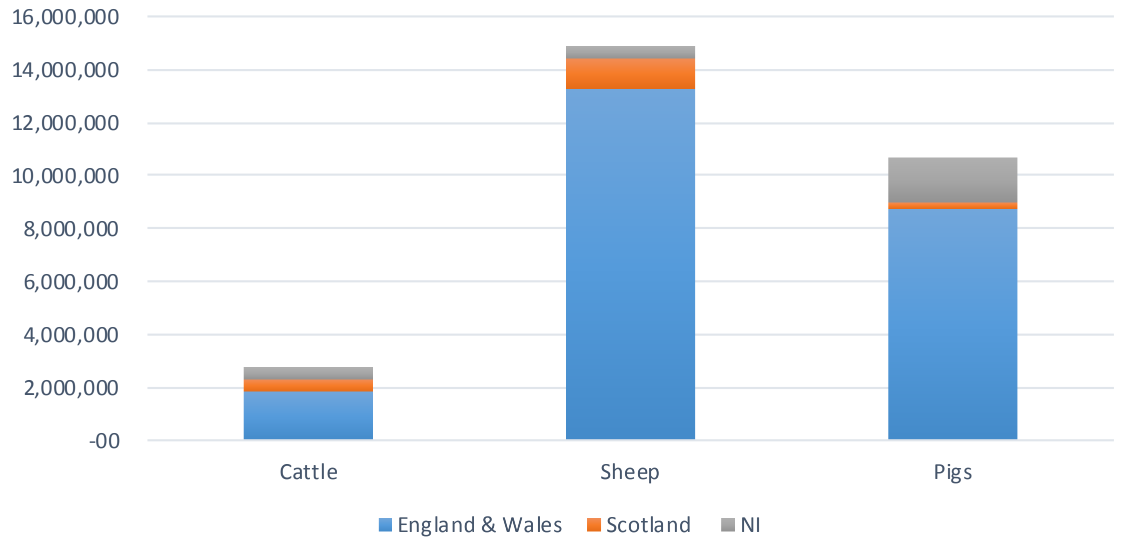


Figure 2 Number of cattle, sheep and pigs slaughtered in 2017 in the UK

57. As shown in **Table 4**, the duration of sea journeys differs substantially, including 01:30 hours from England to France to 13:00 hours from Scottish Islands to mainland Scotland. Please note that the journey times presented in **Table 4** include some crossings which do not currently include animal transport routes. There are also many other shorter ferry journeys not listed, particularly in Scotland

[14]Cattle, sheep and pigs-https://www.gov.uk/government/statistics/cattle-sheep-and-pig-slaughter/
Poultry - https://www.gov.uk/government/statistics/poultry-and-poultry-meat-statistics

58. Time during transport by sea is generally in a road vehicle carried on a ferry, and is considered 'journey time'. An exception to this is for transport from the Scottish isles to mainland Scotland, in special dedicated livestock transport containers where the time period (the time during the sailing) is considered to be "neutral time".

59. The concept of "neutral time" was developed to allow EU transport legislation to be applied to livestock transport by sea in dedicated livestock vessels or systems providing equivalent conditions, as the legislation did not specify maximum permissible journey times for these conditions. Animals transported in this way are provided with a greater space allowance than road vehicle requirements (as set out in Annex I, Chapter VII), with superior arrangements for inspection by attendants, feed, water and ventilation as required (as set out in Annex I, Chapter IV). As there is no maximum limit in legislation on the duration of a voyage in these circumstances, the time spent is interpreted as neither rest nor travel time for the purposes of EU journey time specifications but is termed "neutral time" for practical purposes in the UK. This interpretation does not apply to journeys in road vehicles on ferries as these have a lower permitted space allowance and typically have less ideal arrangements for inspection and attending to animals during the voyage. Any transport on a road vehicle on a ferry is therefore interpreted as part of the overall road journey time.

Table 4 The typical durations of the main ferry crossings operating within the UK and EU. [15]

From - To	Route	Duration
England to France	Dover to Calais	01:30
		03:00
	Dover to Dunkirk	02:00
	Newhaven to Dieppe	04:00
	Poole to Cherbourg	04:15
	Portsmouth to Caen	05:45
	Portsmouth to Le Havre	08:00
	Ramsgate to Calais	04:30
England to Netherlands	Harwich to Hook of Holland	07:30
	Hull to Rotterdam	11:45
	Killingholme to Hook of Holland	11:00
	Newcastle to Ijmuiden	16:30
England to Republic of Ireland	Liverpool to Dublin	07:00
Northern Ireland to England	Belfast to Heysham	08:00
	Belfast to Liverpool	08:00
	Warrenpoint to Heysham	08:00
Northern Ireland to Scotland	Belfast to Cairnryan	02:00
Republic of Ireland to England	Dublin to Heysham	09:00
	Dublin to Liverpool	08:00
Republic of Ireland to France	Dublin to Cherbourg	19:30
	Rosslare to Cherbourg	17:00
Scotland to Northern Ireland	Cairnryan to Larne	02:00
Scotland to Scotland	Aberdeen to Kirkwall	06:00
	Aberdeen to Lerwick	13:00
	Scrabster to Stromness	02:00
Wales to France	Pembroke to Cherbourg	04:01
Wales to Republic of Ireland	Fishgaurd to Rosslare	03:00
	Hollyhead to Dublin	03:15
		01:49
		03:00
		03:15
	Pembroke to Rosslare	04:00

[15] https://www.freightlink.co.uk/ferry-routes/from-uk%20mainland-to-republic%20of%20ireland?vehicle-length=2_13&currency=GBP [Accessed April 2018]

PART 3: DISCUSSION OF THE MAIN ISSUES RELATED TO THE TRANSPORT OF ANIMALS.

60. Poor welfare during transport can be identified by alterations in a number of physiological indicators. For example, increases in free fatty acids, urea, β-hydroxybutyrate and decreases in glucose are seen during feed deprivation. Dehydration causes increases in osmolality, total protein, albumin and packed cell volume. When animals are physically exerted, creatine kinase and lactate are increased. The most commonly known indicators during transport are; increases in cortisol and motion sickness, which can cause an increase in vasopressin. Other indicators include; increased heart rate and respiration rate[16]. These physiological indicators could in principle be used as measures of poor welfare during transport and can be used experimentally to assess the impacts of transport systems. Practical management and handling procedures should be in place which reduce these physiological impacts (and the physiological measures which result), as much as feasibly possible, during transport. [17]

61. Some of these biochemical indicators may also indicate psychological stress (e.g. cortisol), however in many cases observation of animals and their behaviours will be more informative. Direct observation or – for animals with low stocking density or in transport with sufficient head-space – CCTV could be used for both experimental studies and potential routine monitoring of stock.

62. Most participants who participated in the stakeholder engagement acknowledged that the EU Regulation 1/2005 does provide a framework which protects the welfare of animals during transport, but on some occasions the participants indicated that the regulation failed to fully protect welfare, with the main concerns arising from lack of training and education, undetected non-compliance, and relatively low levels of enforcement or variation in the interpretation of regulations.

63. Enforcement of the EU Regulation 1/2005 was one of the main concerns for stakeholders. If the EU Regulation is properly enforced, then this would allow animals to be transported within, or outside of the UK, with reasonable levels of protection. One recurring reported issue regarding enforcement was variable interpretation and implementation between the Member States and regions (and within the UK). Enforcement of the EU Regulation was also identified in the EC Commission's report as an area of concern. [18]

64. The EU Regulation 1/2005 covers all vertebrate animals, but there are sections that do not fully protect certain species of animal, or stages of animal production. For example, there is

[16] Systematic review
[17] Knowles and Warriss, 2000.
[18] Report from the Commission to the European Parliament and the Council on the impact of Council Regulation (EC) No 1/2005 on the protection of animals during transport.

little mention of fish, cats and dogs, or specific attention to young or older ('spent') animals. While species-specific requirements, and specific physiological requirements are important to ensure the welfare needs of all animals are met during transport, more consideration should be made for breed variation within species and for young or older animals.

65. The EU Regulation 1/2005 made recommendations to protect the welfare of animals during transport through requirements such as ventilation, temperature and stocking density. Many of these were drawn from expert opinion or limited scientific evidence, and in many cases do not cater to specific classes of stock (for example, specific requirements for species, age, weight, sex).

66. Animals are sometimes transported when they are not fit for transport (see non-compliance, **Table 5**). It was suggested to FAWC that non-compliances in many cases stem from uncertainty over where the limits of acceptability lie. A lack of training and education in the decision making process regarding 'fitness for transport' may be a contributing factor to the increased levels of non-compliance of the regulation, with a resultant lack of awareness of what constitutes a 'fit' or 'unfit' animal. Drivers and attendants must obtain a Certificate of Competence for the species in which they are transporting, but once issued this is valid for life; there is no compulsory on-going training or education required for anyone who is involved with transporting animals.

67. **Table 5** indicates the number of transport inspections and non-compliances in the UK during 2017. As shown, the category with the majority of non-compliance breaches is 'fitness to travel', followed by 'transport practices'.

68. There are limited options for animals that are not fit for transport. Farmers may undergo financial losses if they are unable to move the animal to slaughtering facilities and instead have to euthanise it on farm and pay for disposal, or have a knackerman or hunt kennel attend. Due to legislative and economic limitations, on-farm emergency slaughter for human consumption, is only rarely possible. There is therefore a significant incentive for farmers to try and send animals to slaughter. This increases the risk that animals may be transported to slaughter which are unfit to transport. Mobile slaughtering facilities that can travel to farm have been trialled but have not had commercial success to date.

69. One of the largest concerns identified by the animal welfare group stakeholders, was that there was a lack of control over an animals' welfare once that animal was outside of the UK regulatory environment. This is particularly pertinent for animals leaving the EU and entering third countries. The slaughter of animals is regulated by Council Regulation (EC) No 1099/2009, which is applied to both the UK and EU, but if these animals are further transported to third countries, then there may be little or no regulation to protect their welfare.

70. There is a discrepancy between the drivers' allocated driving hours for road safety reasons and the number of hours an animal may be transported before it requires a break / rest stop.

Regulation (EC) 561/2006, stipulated the drivers' hours: 9 hours daily driving limit which can be increased to 10 hours twice a week, with a maximum 56 hours weekly driving limit. The driver must have a break for 45 minutes after 4.5 hours driving. These requirements differ from those of EU Regulation 1/2005, where animals can be transported for 14 hours before a break (cattle, sheep and goats) and 24 hours for pigs and horses. This can impact animal welfare by prolonging journey times for animals, and sometimes unnecessary loading / unloading of stock, increasing stress.

71. Responsibility for enforcement of the Regulation lies with Local Authorities. A non-compliance is considered if there is a breach of the 1/2005 regulation requirements. A serious non-compliance could be considered as something that would compromise the welfare of the animal significantly. APHA act as the National Regulator on behalf of Defra, Welsh Government and Scottish Government. [19]

72. Lack of enforcement of EU Regulation 1/2005 has been reported as an issue by many respondents from various stakeholder groups with the enforcement picture being complex and varied within the countries of the United Kingdom. In addition to enforcement action the Regulation also provides powers to Competent Authorities to take regulatory action which can be alongside enforcement action to safeguard animal welfare, or to improve compliance of transporters. A Competent Authority is responsible for issuing Transporter Authorisations, Drivers Certificates of Competence and Vehicle Approvals. As the issuing body the Competent Authority is able to take regulatory action by either adding conditions, suspending or revoking the authorisations and approvals it issues with the view of actions being taken to improve compliance. Regulatory and enforcement action are inter-dependant and joint working between the responsible bodies should be maximised for the best effect. However feedback showed that the multi-body approach currently in place is limited by the following factors - lack of standardisation in approach, prioritisation amongst LA's varies with different levels of knowledge/ specialisms (LAs are responsible for more than animal welfare based issues). Enforcement/Regulatory responsibility is as follows:

- GB - Local Authorities are the statutory body responsible for taking action under the implementing Orders of the Regulation in each country of GB. APHA is the Competent Authority acting on behalf of Defra and the devolved administrations of Scotland and Wales.
- In Northern Ireland Daera acts as the Competent Authority for the purposes of the Regulation and also takes enforcement action.

73. According to the EC Commission report on the 1/2005 EU Regulation, one of the reasons for the lack of enforcement is that the Regulation is differently interpreted in different areas, and there is a lack of consistent control to enforce the EU Regulation by the different member states. Part of the issue is that it is difficult to bring cases to prosecution, due to the difficulty

[19] The responsibilities and obligations of National Regulator are set out in Article 26 of the Regulation.

in proving that the animals were in fact suffering, and unfit at the start of loading on to the vehicle[20].

74. The 1/2005 Regulation states that no animal should be subject to any unnecessary suffering, the animal should be fit for transport, vehicles must be suitable, and journey time limits and space allowances must be applied as required. As shown in **Table 5** the number of non-compliances is highest for animals, which are not fit to travel, when being sent to slaughter.

75. In a recent FAWC report, it was highlighted that sustainable agriculture must meet the needs of animal welfare[21]. To maintain sustainable agricultural practices, animals should not unnecessarily be transported long distances, if they could be slaughtered/ reared/ bred in closer proximity.

76. Loading, unloading and handling are often described as the most stressful part of the transport process, this is because the animals are moving into unfamiliar surroundings, and they may have to walk up or down a range of ramp surfaces and angles. Mixing of the animals may lead to fighting to establish a hierarchy. For the stockpersons this can also be a stressful time, as the animals may be reluctant to board the transport vehicle. Therefore, careful management of handling, loading and unloading are critical to ensure that the welfare of the animals is maintained.

77. The systematic review based on published scientific literature, highlighted that animals travelling through markets experience increased levels of bruising, and it was proposed[22] that poor handling was responsible for the increased levels of bruising.

78. All forms of transport are considered stressful and may impact the welfare of the animals. Transporting animals by sea includes motion - up and down and side to side, which can cause sea sickness in pigs and increased heart rates and reduced rumination in sheep. The uncertainty of the sea state also poses transport risks. For example, poor weather can increase the sea motion, and extreme weather may also prevent vessels from sailing, resulting in increased delay, sometimes with animals confined on waiting transport. Poor ventilation during sea transportation can, result in increased temperature and humidity, which can lead to airborne pathogen spread, causing serious health issues for stressed animals.

---

[20] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the impact of Council Regulation (EC) No 1/2005 on the protection of animals during transport. https://ec.europa.eu/food/sites/food/files/animals/docs/aw_practice_trans_10112011_report_en.pdf (accessed January 2019)

[21] FAWC Review, Sustainable agriculture and farm animal welfare, 2016.

[22] Weeks et al. (2002) Influence of the design of facilities at auction markets and animal handling procedures on bruising in cattle. Vet. Rec.

Table 5 The number of transport inspections and non-compliances recorded in the UK during 2017[23]

Species	Bovine	Porcine	Ovine ~ Caprine	Equine	Other Species*	Poultry	Dogs / Cats
Number of Vehicles where document(s) checked	6,533	1,401	9,004	1,906	1,114	1,156	652
Category of non-compliance [24]							
1. Fitness of animals	224	278	196	1	51	1,560	-
2 Transport practices, space allowances, height	26	8	26	6	66	3	32
3. Means of transport etc.	24	15	45	13	83	3	-
4. Watering and feeding, journey times and resting periods	-	-	4	-	1	-	-
5. Documentation	36	21	42	35	71	1	-
6. Other	46	10	36	-	11	-	-
Total	**356**	**332**	**349**	**55**	**283**	**1,567**	**32**
Penalties imposed	1	1	-	-	-	-	-
Enforcement	219	91	264	60	269	10	32

*"other" animals are zoo animals, lemur, emu, fish, reptiles and birds.

[23] APHA.
[24] Note: this includes all non-compliances recorded at abattoirs by FSA/FSS /NI and reported to LAs, as well as others recorded by LAs

PART 4: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

79. An overarching conclusion of this FAWC opinion is that for many species (e.g. cats, camelids, fish, goats) and breeds within species (e.g. the difference between Shetland ponies and Shire horses, Dexter and Limousin cattle), there is a requirement for more research in order to make specific informed recommendations. However broad principles can be suggested and reasonably applied subject to educated and informed monitoring of the wellbeing of the animals when in transit.

80. The EU 1/2005 Regulation provides a basic framework that does offer a level of protection for animals during transport. However, serious practical implementation issues do exist, including; lack of consistent enforcement and policing of the Regulation, recognising fitness for transport, establishing acceptable temperature ranges, ventilation rates and stocking densities for the individual animals, determining maximum journey times based on evidence, and a requirement that anyone transporting animals should receive relevant training.

81. Some of the issues identified in the 1/2005 Regulation have been noted by FAWC and recommendations have been made (below) as to what improvements can be made to improve the regulatory regime.

82. This opinion has identified that there are still significant gaps in knowledge regarding how to maintain the welfare of animals during transport. The most obvious areas of concern are; the lack of evidence to establish maximum journey times, the effects of sea transportation on the welfare of animals and establishing species-specific and within species, breed variable physiological and psychological needs during transport.

83. The EU 1/2005 Regulation, does not fully distinguish the different transportation needs of animals with respect to age, size, sex, status and breed. For example, recently weaned pigs, are particularly sensitive to temperature changes and are relatively ‘fragile’, whereas finishing pigs are much more adept at travelling. Better care and driving quality may be required for some types of animal, for example; cull animals on the way to slaughter, as these animals may be less able to withstand transport. Some animals have specific feed and water requirements, for example; pigs may require continuous provision of water on long journeys. A number of knowledge gaps in the understanding of species-specific requirements have been identified as a result of the work described in this opinion.

Recommendations

84. The following FAWC recommendations are provided in points 84 to 105. These recommendations are designed to improve the overall welfare of animals during transport.

General

85. Recommendations to improve aspect of animal welfare during transport should be based on best evidence and robust scientific data. FAWC have identified (and this is supported by the findings of the systematic review conducted by SRUC and UoE) that there are significant species-specific and subgroup-specific (e.g. young, juvenile, adult or end of life young, weight, shorn/unshorn, breed) knowledge gaps for animals during transport, for example: there are no maximum journey time and appropriate temperature ranges established for the range of different species, nor are optimum rest periods determined based on evidence (See Tables 10 to 15). A key area for research would be vehicle design alongside the competence of the handler/driver, as the combination of the vehicle and the driver is the factor that will be most influential in affecting animal welfare. Vehicle design should also factor in species specific requirements. Future design of vehicles should also consider escape hatches/ routes that allow animals to be rescued if there is an emergency e.g. vehicle accident. Animal carrying vehicles, particularly those used for long journeys, should provide access for the full inspection of animals during the journey i.e. ladders to reach all compartments of the vehicle and appropriate intervention if necessary. Finally, an area of research would be to examine the duration and also the quality of the journey to maintain the welfare of animals during transport. The use of CCTV within the animal carrying area or areas was reported as being of value for the haulier who could then monitor the animals during a journey.
    a. *FAWC recommends that industry and academic institutions should aim to provide the latest species specific and subgroup-specific (young, juvenile, adult or end of life, weight, shorn/ unshorn, breed) scientific research findings for all animals (livestock, equine and companion animals). Any new scientific findings should be used to inform areas of concern when transporting animals. There are a number of knowledge gaps that have been identified (**Appendix A**) and that these knowledge gaps should be considered as research priorities, as these could have significant implications for the welfare of animals. More funding should be made available to academia to fund independent research (i.e. no conflict of interest) to fill these knowledge gaps and to adequately understand the welfare issues that animals may experience during transport.*

86. Studies which are designed to examine the impact of transportation on the welfare of animals, should include a follow-up period to determine the longer-term impact (post journey) on health, morbidity and mortality. The results of exposure to physiological and psychological

stressors from transport may only manifest in the days or weeks following a journey (e.g. shipping fever in cattle), and so any data gathering should extend into this period. FAWC identified this issue whilst reviewing the systematic review and evidence submitted from the CfE.

a. *FAWC recommends that data is collected from experiments before, during and for at least two weeks post transport to assess any long term implications to the health, morbidity and mortality of the animals after transport. This recommendation should apply to all animals (livestock, poultry, equine and companion).*

Live animal exports

87. The UK government published a Call for Evidence on controlling live exports for slaughter and to improve animal welfare during transport after the UK leaves the EU. FAWC received all of the responses (366) and met with a number of different stakeholders who contributed to the CfE for further discussions. A number of concerns were identified from the CfE with reference to live animal exports, with the largest expressed concern being that there was lack of control in maintaining the welfare of these animals once they are transported overseas to another country. To further explore the implications of live exports on animal welfare, FAWC visited Ramsgate Port to see live exports and portal inspections. FAWC noted that there is limited opportunity to inspect fully or examine the individual animals at the Port and there should be a safe and secure place to safely unload and reload the animals on the docks whether for imports or exports. Whereas, when FAWC visited Aberdeen facilities (movements from Orkney or Shetland) there were opportunities to fully inspect the animals. There are also a number of additional factors which may impact the welfare of the animals being exported, particularly where poor weather may prevent animals' crossing over the sea and thereby extending the time animals are subject to a journey. One of the main issues identified by FAWC was that the number of animals that are transported to an abattoir for slaughter are either traveling vast distances to find a suitable abattoir i.e. cull sows traveling from NI to GB as there are no suitable abattoirs that are designed to slaughter these animals. Or an animal that is transported for slaughter that is passing several abattoirs in the UK to be slaughtered overseas. These examples indicate the potential stress these animals may have to endure during the final stages of life, when there are better alternates available or could or should be available. Breeding animals may be subject to export so as to meet a requirement for improved genetic capabilities and these journeys should be considered as providing a more justifiable reason for an export journey by comparison with those related to further finishing or slaughter where such actions be could be carried out within the host country. However, FAWC understand that currently where there are no or limited facilities then an overseas journey maybe the only solution.

a. *FAWC recommends that animals are only transported if it is absolutely necessary and that the most welfare considerate route is chosen; which is a combination of journey quality, including they type of transport, duration and suitability. Therefore, animals should not be transported longer distances if suitable alternatives are available. Transporters intending to export animals to be slaughtered or further fattening in a* *different country should apply to APHA for consent to do so, indicating reasons why alternative arrangements have not been made.*

b. *FAWC recommends that there is a review of the availability of abattoirs related to the points of production and particularly mindful of end of life requirement. This will identify where abattoirs need to be sited in order to meet the needs of farmers and to minimise journey times and thereby meet the welfare needs of animals.*

c. *FAWC recommends further research into the feasibility of the economics, design and use of mobile slaughter facilities so as to reduce the need to transport animals over long distances particularly with regard to sea crossings.*

Fitness for Transport

88. Non-compliances with the EU Regulation has potential to cause a considerable number of welfare issues. FAWC has identified areas that may lead to non-compliance with the 1/2005 Regulation. These include; a lack of training and education, or guidance on transport requirements. During stakeholder engagement, it was highlighted that there is often uncertainty, or a lack of clarity, regarding who is practically responsible for the welfare of the animals during the transport process, despite this being specified in Article 5 of the 1/2005 Regulation. The lack of guidance / criteria regarding the 'practical detail' of decision making for fitness for transport, and the specific welfare needs of different species of animals during transport was considered an area which required urgent attention for all involved within the transport process.

    a. *FAWC recommends that guidance such as the EU "Animal Transport Guides"*[25] *should be applied and promoted by the industry and government. These best practices guides have been researched and designed to improve the welfare of animals during transport and have so far been provided for: cattle, sheep, pigs, poultry and horses. Other guides exist for: goats*[26]*, dogs, cats*[27] *and fish*[28].

89. The non-compliance of fitness for transport was identified as an important issue in the Call for Evidence and stakeholder engagements. Transporting animals that are not fit for transport causes suffering. Fitness should not just relate to individual pathological conditions, but also the suitability of a group of animals to undertake the journey planned, and in the conditions prevailing at the time. Factors in this would include weather, the robustness (or frailty) of the stock (e.g. young or old animals) or specific contemporary transport issues (e.g. known delays due to road maintenance). One of the issues identified with fitness for transport is that there are a number of derogations in the 1/2005

[25] http://animaltransportguides.eu/about-the-project/
[26] http://adlib.everysite.co.uk/resources/000/263/138/PB12544b.pdf [Accessed February 2019].
[27] https://ec.europa.eu/food/sites/food/files/animals/docs/aw_eu-strategy_study_dogs-cats-commercial-practices_en.pdf [Accessed February 2019].
[28] https://ornamentalfish.org/wp-content/uploads/Transport-code-final.pdf [Accessed March 2019].

EU Regulation. These derogations[29] can in some cases be misconstrued and as a result animals may be mistakenly considered as suitable for travel. This can pose serious animal welfare concerns and has led to many non-compliances (see **Table 5**).

   a. *FAWC recommends that a more specific definition of fitness to transport should be created, and the industry/ levy boards could act to promote improved dialog and understanding regarding criteria fitness for transport and suitable transport conditions. Tools such as videos, posters, leaflets and written guides could all be used using the information based on best practice guides (as suggested in paragraph 86). More training should be provided to enable owners/ farmers/ transporters to identify animals that are not fit for transport. This recommendation should apply to all livestock, poultry and equine animals.*
   b. *FAWC recommends that current penalties to deter people from transporting animals in breach of the Regulation should be reviewed. Understanding why people breach the regulation could influence future penalties such as fixed term notices or to resource additional support for transporters/ farmers to make informed decisions when transporting animals in the future. More research is warranted to understand the human behaviours of transporting animals.*

90. Registered horses, for which transport can include: breeding, cultural, and competition, are exempt from some provisions in EU 1/2005 Regulations. Due to the high economic value of these animals they are usually transported in good welfare conditions consistent with ensuring the maintenance of their value. However, once these animals retire, they retain their status as 'registered horses', but are at risk of experiencing notably lower standard of transport and therefore may experience 'poorer' welfare due to their exemption from the welfare provisions. This discrepancy should be remedied.
   a. *FAWC recommend that horses should not be classified as either registered or unregistered in any proposed Regulation. Instead, the terms registered or unregistered should be removed altogether from transport legislation and that all horses should be reclassified solely as "horse(s)". This would ensure that all horses are covered under the same Regulation and that the highest welfare standards are applied[30].*

[29] Sick or injured animals may be considered fit for transport if they are:
(a) slightly injured or ill and transport would not cause additional suffering; in cases of doubt, veterinary advice shall be sought;
(b) transported for the purposes of Council Directive 86/609/EEC (1) if the illness or injury is part of a research programme;
(c) transported under veterinary supervision for or following veterinary treatment or diagnosis. However, such transport shall be permitted only where no unnecessary suffering or ill treatment is caused to the animals concerned;
(d) animals that have been submitted to veterinary procedures in relation to farming practices such as dehorning or castration, provided that wounds have completely healed.

[30] Note: This recommendation does not cover definition of horses for health certification or other purposes – only transport.

Means of Transport

91. Both the duration and the quality of a journey may play a role in the amount of stress that the animals experience during a journey. Under the EC 1/2005 Regulation, a vehicle requires inspection and approval if it is used to transport animals for over 8 hours into the rest of the EU, or up to 12 hours within the UK. Most vehicles are used for transporting animals for less than 8 hours travelling time, but may not be suitable for the purpose intended. For example, leaf suspension livestock trailers were associated with an increased the likelihood of bruising in pigs in one study[31]. Furthermore, the systematic review and stakeholder engagements identified that the quality of the journey is compromised if the vehicle, and the animals it contains, is subject to: erratic braking, uneven road surfaces, rapid acceleration, and cornering. Poor driving or road conditions may lead to more stress, injury and poor welfare, regardless of the journey length. The combination of poor driving, unsuitable vehicles or road conditions with increased journey length could increase the risk of stress, welfare impact and injury that the animals may experience.
   Provisions to alleviate stress, for example, equipment for provision of food and water, should be in complete working order, and all animals should have access to them. These provisions should suit the needs of the animals they are intended to transport.
   During a visit, FAWC were impressed with the use of CCTV inside a transporter which allows the driver to have knowledge of how the animal is travelling. The addition of CCTV added to transporters does require further exploration but is a promising step towards real-time monitoring of the animals during journeys.
   a. *FAWC recommends that **all** vehicles that are used to physically transport livestock, poultry and horses (i.e. lorries, trailers, horse boxes) should be inspected by Vehicle Approval Bodies, regardless of journey length. It is anticipated that these requirements will be rolled over several years due to the number of vehicles that are used for transporting these animals. All vehicles that are used to transport animals will be issued with a certificate. Whereas, vehicles which transport other vehicles containing animals i.e. trains or ships should follow similar guidance laid out by the International Air Transport Association (IATA) Live Animals Regulations[32].*
   b. *FAWC recommends that accelerometers should be retro-fitted to all vehicles that are used to transport livestock, poultry and horses and acceleration, braking, cornering and uneven road surfaces should be recorded by these devices. The recordings of these devices, should be submitted to the LA or APHA on request; for example, if there are increased levels of lameness, bruising or dead on arrival animals noted at the slaughterhouse.*

[31] Dalla Costa et al. (2016) Ease of handling, physiological response, skin lesions and meat quality in pigs transported in two truck types. Archivos de Medicina Veterinaria. 48, 3.
[32] https://www.iata.org/whatwedo/cargo/live-animals/Pages/index.aspx [Accessed March 2019]

Handling at markets

92. Animals that go through markets may undergo multiple events of loading and unloading over a short period of time, which may be greater than the stress of the actual journey. To reduce the stress and injury during loading and unloading, careful handling of the animals is required, but research has shown that increased bruising can occur due to poor handling in markets, particularly in cattle[33]. Markets in England and Wales are licensed on the basis that specific requirements and conditions are met. Most of the required conditions aim to prevent the spread of disease, and for this reason a biosecurity officer must be employed[34]. The animal gathering licence does address animal welfare, for example by preventing sick or injured animals from being sold. In 2005, FAWC produced a report on the Welfare of Farmed Animals at Gatherings[35] and noted that markets should have effective mechanisms to safeguard the welfare of the animals at markets, in particular during the loading and unloading of the animals. FAWC recognise that markets' have made substantial moves towards improving the welfare of animals in markets, with the market operator having a responsibility to monitor the welfare of the animals at markets. However, by not having an independent person employed i.e. someone from the LA or APHA to monitor the welfare of animals has led to difficult situations and conflict of interests between the farmer and market operator if the welfare of the animal is compromised.
    a. *FAWC recommends that further scientific work is needed to determine what improvements can be made regarding handling, including loading and unloading in markets.*
    b. *FAWC recommends that markets should require an animal welfare licence in addition to the animal gatherings licence. The licence would serve to protect animals during their time in a market, including the time from which animals are unloaded until they are loaded onto the vehicle, and also during sales. If the market breaches any part of the licence, then this will be suspended or withdrawn. The animal welfare licence will cover the prevention of: poor handling, unfit animals being sold or transported, and poor conditions required for retention of animals at the market for prolonged periods of time. The licence will require input from the LA animal health officer(s) to enforce these requirements.*
    c. *FAWC recommends that further work should be carried out to identify the different times animals spend at markets, and to identify effective ways to monitor and record journey time through markets. FAWC has acknowledged that a rest period is only achieved when animals are able to show natural behaviours (including eating drinking and lying), which they may be unable to do in markets. Therefore, the amount of time animals spends in markets should be recorded, and a maximum time*

---

[33] Weeks et al. (2002). Influence of the design of facilities at auction markets and animal handling procedures on bruising in cattle, 150, 24.
[34] https://www.gov.uk/guidance/get-a-licence-to-hold-an-animal-gathering
[35] FAWC report on the Welfare of Animals at Gatherings: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/325209/FAWC_report_on_the_welfare_of_farmed_animals_at_gatherings.pdf [Accessed March 2019].

an animal spends at a market should be determined. These recommendations apply to all animals that go through markets.

Space Allowances

93. Space allowances are likely to be important for the animal's welfare. If the space allowance is low, then the animals will be in cramped conditions and it may be difficult for the animals to regulate their body temperature, and there may be increased risk of trapping, compression, 'stepping on', or physical damage. Optimal stocking density is essential to maintain the welfare of animals during transport, and FAWC advised the UK government on space allowances in 2013. [36]
    a. *FAWC recommended an allometric system (see tables 9 to 11 under the heading space allowances) to determine the stocking density of sheep, cattle and pigs. Stocking density for horses should be determined using kg/m2 and not m2/ animal. This stocking densities should be applied in any proposed policy reform. Space allowances that have not been identified based on scientific literature require further research to determine appropriate stocking densities for all species intended for travel.*

94. During transport, animals other than poultry require enough head space to stand in their natural position with enough space above them to ensure adequate ventilation and to prevent any injury or suffering. FAWC advised the UK government in 2013 that headroom allowance was important to maintain animal welfare during transport. FAWC recognised at that time that there was very little research on this topic, until further research is conducted, the following headroom heights are considered to be the minimum[37].
    a. *FAWC recommends that the following headroom height requirements as provided in **Table 6** in any proposed policy reforms.*

[36] FAWC advice on space and headroom allowances for transport of farm animals, 2013.
[37] FAWC advice on space and headroom allowances for transport of farm animals, 2013.

Table 6 Recommended headroom heights for different species (height ABOVE full standing head height).

Species	Recommendations	Reference
Dairy cattle	20 cm	[38]
Beef cattle	30 cm	[3]
Sheep	22 cm	[39]
Pigs	9 cm	[40]
All other animals (excluding poultry)	20 cm above the head	[41]

Transport Practices

95. The EU 1/2005 Regulation defines a commercial journey as: *Transport for commercial purposes is not limited to transport where an immediate exchange of money, goods or services takes place. Transport for commercial purposes includes, in particular, transport which directly or indirectly involves or aims at a financial gain*. This definition is not fully clear and may cause confusion for anyone transporting animals either for commercial or non-commercial purposes. Regardless if animals are transported for either commercial or non-commercial purposes, they still may experience the same levels of stress or welfare issues associated with transportation.

    a. *FAWC recommends that the definition of commercial journeys that is in the 1/2005 Regulation should be removed and instead all animals should come under the same proposed regulatory reform. This would allow **all** animals (livestock, poultry, horses and companion) to be afforded the same level of protection regardless if they are being moved commercially or not. There are a lot of "non-commercial" movements that are not covered by the current 1/2005 Regulation and these animals may undergo welfare concerns during transport, but are not recognised in the current transport Regulations. This proposed recommendation does not require all people who transport their animals to obtain a CoC, instead the animals that are currently listed (i.e. livestock, poultry and horses) would still require CoC, but transportation of companion animals does not. See paragraph 98 for further information on CoCs.*

[38] Lambooij, E., Reimert, H.G.M., van der Werf, J., Hindle, V.A. (2010) Compartment height in cattle transport vehicles. Available at: http://edepot.wur.nl/157460
[39] Jones, T.A., Look, A., Guise, H.J., Lomas, J. (2002) Head height requirements, and assessing stocking density for sheep in transit. Veterinary Record, 150, 49-50
[40] Jones, T.A. (2003) Study to investigate the space above the head and shoulders of pigs and cattle when standing during transport. Defra Project AW0816 available at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=12041#RelatedDocuments
[41] SCAHAW. (2002) The welfare of animals during transport (details for horses, pigs, sheep and cattle). Scientific Committee on Animal Health and Animal Welfare

Thermal conditions and Ventilation

96. Throughout a journey, an animal may experience a range of different temperatures and cope, but extreme temperature can cause marked suffering and should be avoided or urgent action taken to reduce any deleterious effect. The EC 1/2005 Regulation stipulates that vehicles for long journeys should have a ventilation system which is capable of maintaining the temperature throughout the journey of between 5 ºC to 30 ºC. The ventilation system must be capable of operating for at least 4 hours, independently of the vehicles engine. The Regulation does not state that animals should not be transported when the external temperature is above or below this range, although transporting with temperatures outside this range within the vehicle would be a non-compliance. Furthermore, the Regulation does not specify that the temperature and ventilation be controlled or monitored on short journeys of less than 8 hours to the EU or less than 12 hours within the UK. Shorter distance journeys will still have the potential to cause severe welfare impacts if temperature cannot be adequately controlled and ventilation is not adequate. Determining temperature ranges for animals during transport is a difficult process as there are a number of factors to consider and currently a lack of evidence to support these temperature ranges, but extreme temperatures may pose a serious welfare concern during transport.
    a. *FAWC recommends that more research and evidence is required to determine the acceptable temperature ranges for the different species and classes of livestock, horses and companion animals i.e. age, breed, sex, shorn/ unshorn that are transported. Until this time, FAWC have suggested temperature ranges for cattle, sheep, pigs and poultry (**Appendix C**). **These temperature ranges should only be used as a guide and only when outside temperatures are exceeded i.e. outside 5ºC to 30ºC.** Where temperature ranges are not defined in Appendix C, then the current 1/2005 Regulation should be applied to all other animals.*
    b. *FAWC recommended that a maximum and minimum temperature should also be devised for all animals (farm, equine and companion animals) where they are not permitted to be transported outside of these extreme temperatures ranges. This should be a research priority due to the increased levels of extreme temperature ranges that are being experienced, and are likely to experienced, in future. Vehicle design should also be considered when considering the thermal requirements of animals.*

Long journeys

97. There is little scientific research on the interaction of journey duration and journey experiences and direct impacts of journey 'length' (distance / duration) on adverse welfare (or health) effects. As such, it is not possible to make evidence-based recommendations on the maximum journey length / duration for all animals that are transported. However, as according to the current legislation, in all cases, and wherever possible, the shortest journey length must be selected. Currently, in the 1/2005 Regulation, there is no absolute maximum journey limit. If the transporter has not reached their final destination (after the animals have had their mid-journey rest) then these animals must be unloaded, fed and watered and be rested for a **minimum** of 24 hours at a control post before the whole process is restarted again

and repeated again and again This may pose significant animal welfare concerns, as animals in theory may be transported indefinitely.

a. *FAWC recommends that, where robust scientific findings are available regarding species- specific or subgroup-specific (young, juvenile, adult or end of life) journey time requirements, then these should be adopted in the new regulation. Based on the scientific output from the systematic review, there are desirable maximum journey time limits for some species of animals which should be applied in policy reforms (**Table 7**). The **desirable maximum journey time limits should not be exceeded and the times indicated in the table should be considered the absolute maximum.***

b. *FAWC also acknowledges that the shortest journey time should be applied in all circumstances, therefore FAWC recommend that if any journey goes beyond 21 hours for all animals (cattle, sheep, and other livestock and companion animals that are not mentioned in **Table 7**) then written consent is required and submitted to APHA for review. Reasons to why the journey needs to go beyond 21 hours should be fully justified and alternative options should be noted. If an extension of 21+ hours is granted, then a mid-journey rest stop will be required – see paragraph 97).*

Table 7 The desirable maximum journey times for some species of animals during transport based on the systematic review.

Species	Desirable maximum journey time limits
Broiler chickens	4 hours
Pigs	18 hours
Newly weaned pigs	8 hours*
Halter broken / Non halter broken horses	12 hours
Calves (up to 9 months)	9 hours
Recently hatched chicks	24 hours (FAWC recommendation 21 hours, written consent required to travel 24 hours*).
Cattle	29 hours (FAWC recommendation 21 hours, written consent required to travel 29 hours*).
Sheep	48 hours (FAWC recommendation 21 hours, written consent required to travel 48 hours*).
All other animals (until scientific evidence is provided, no animal should be exposed to journeys longer than 21 hours).	21 hours

* FAWC recommendation

98. Young animals may undergo increased levels of stress due to a number of different age related factors including; the weaning process having taken place just before transport, difficulty in regulating body temperatures, and a naive immune system. A suitable rest break may help to alleviate some of the stress imposed during transport. However, it may be appropriate to define a finite transport time which is suitable for younger animals. As

mentioned above (paragraph 95), not all species of animals have recognised maximum desirable journey durations. Therefore, because of increased welfare concerns with transporting younger, un-weaned animals, setting a maximum journey time may be an appropriate policy step to improve the welfare of younger animals. During stakeholder engagement, illegal puppy smuggling was identified as an emerging welfare concern, with animals being imported from a number of European countries. Many of these animals are being imported with no vaccination history and may be have been weaned considerably earlier than recommended.

a. *FAWC recommend that a maximum journey time of 9 hours for all un-weaned animals or animals that have been weaned within the last week (all livestock and horses, and companion animals) (except for newly weaned pigs).*
b. *FAWC do recognise the difficulty in implementing this recommendation for companion animals (including illegal puppy smuggling), but would encourage cooperation between the veterinary bodies, APHA and UK government to implement strategies to reduce this illegal trade.*

Journey times and rest periods

99. For long journeys, a mid-journey rest break is essential to allow animals to rest, eat, or drink during the journey particularly where the maximum desirable journey is exceeded. A rest period must allow the animals to exhibit normal behaviour. Therefore, a rest period is not considered rest if the animals are on concrete, in a pen with minimal bedding, or time on a lorry that is not moving. A mid-journey break would not be considered an actual rest but an opportunity for the driver to make any checks on the animals in transit, and to allow the driver to rest. The current 1/2005 Regulation stipulates that a mid-journey rest break should be applied when the proposed maximum journey time is used i.e. 14 hours of travel with a minimum of a 1 hour rest period followed by a further 14 hours of travel. The 1/2005 Regulation stipulates that the 1 hour journey break is a minimum (and therefore a longer break is supported). However, a concern arises from this as there is a need to limit the overall journey length whilst ensuring the animals are suitably rested and allowed to eat or drink during the rest period. Evidence has indicated that sheep may require a 3 hour mid-journey rest break so that they are able to eat and drink. Different species or subgroup-specific (young, juvenile, adult or end of life) will require different rest periods to allow them to adequately rest, and to consume feed or water and stocking density must be suitable to facilitate rest and access to food/water. During stakeholder engagements and as suggested within the systematic review, drivers' hours and animal transport times should be more aligned to help meet some of the concerns identified above.

a. *FAWC recommend that a mid-journey rest period for all animals where there is no determined desirable maximum journey or when the maximum desirable limit exceeds 21 hours (cattle/ sheep, companion animals, livestock, poultry and horses). Mid-journey rest periods should be more aligned to driver time and rest periods from the Regulation (EC) 561/2006, where a rest period of 45 mins every 4.5 hours is recommended (see **Table 8**). If the proposed journey exceeds 9 hours of driving, then* *a second driver is required. By aligning the driver's Regulation to the animal transport regulation, this should improve the quality of driving by allowing the driver to have suitable rest breaks to refresh. However, further research is required to ultimately decide what would constitute the optimum rest periods for both driver and animals.*

Table 8 The proposed breakdown of mid-journey rest periods.

Driver	Travel time	Mid-journey rest time	Travel time	Mid-journey rest time	Cumulative total
1	4.5 hours	45 mins	4.5 hours	45 mins	9 h + 1.5 h (11.5 h)
Drivers swap over					
2	4.5 hours	45 mins	4.5 hours	45 mins	18 h + 3 h (21 h)
Written consent is required to continue the journey beyond 21 hours. If granted, 24 hours rest is performed where animals should be unloaded, fed, watered and opportunity to perform natural behaviours.					
1	4.5 hours	45 mins	4.5 hours	45 mins	27 h + 4.5 h (31.5 h)
Drivers swap over					
Absolute maximum journey duration for cattle - animals must not be allowed to continue to travel.					
2	4.5 hours	45 mins	4.5 hours	45 mins	36 h + 6 h (42 h)
Absolute maximum for sheep duration for sheep - animals must not be allowed to continue to travel.					

100. Anyone transporting animals over 65 km for economic purposes is required to undertake training, and obtain a CoC. A transporter is not required to obtain a CoC if they are transporting animals under 65 km. This results in many animals being transported without the drivers receiving any formal training on animal welfare or fitness for transport. Training and education has been identified as being an important requirements to safeguard the welfare of animals during transport. Training and education may help personnel to take responsibility for their actions, to apply species specific requirements, and to be prepared for any eventuality through contingency planning. Training and education must include all aspects of the transport process, for example: appropriate and improved handling, loading, unloading, recognising when animals are fit for travel, understanding the impact of road conditions,

acceleration, braking and understanding if the vehicle and animal requirements are being met during transport.

a. *FAWC recommends that the 65km barrier that is currently applied to the EU 1/2005 Regulation should be removed and instead anyone who owns or transports livestock, poultry or horses (regardless of distance/ duration) should have a transporter authorisation and CoC. To note, this proposed recommendation <u>does not require all people who transport their animals to undergo a CoC, only the animals that are currently listed</u> (i.e. livestock, poultry and horses) would still require CoC but transportation of companion animals will not. This recommendation is linked to recommendation 93.*

Sea transport

101. All forms of transportation may adversely affect the animal's welfare, but new evidence has been shown that motion at sea – including side-to-side or up-and-down movements – can cause increased stress in sheep and pigs. When sheep are exposed to side-to-side or up-and-down movements an increase in stepping (balancing) behaviours, increased heart rate and reduced rumination occur; all these reactions are likely indicators of stress.[42, 43, 44]. Furthermore, poor ventilation during sea transport has been shown to increase the risk of health problems for animals[45], due to increased moisture and airborne contamination.

a. *FAWC recommends policy reforms which prevent animals from being transported in severe weather and sea conditions where increased side-to-side or up–and-down motions may occur.*
b. *FAWC recommend that vehicles should be carried in locations on vessels designed to provide natural ventilation as far as possible rather than relying on mechanical systems. Where mechanical systems are needed these should be designed and operated to provide the recommended temperature range at all times.*
c. *FAWC recommends that no animals are transported over the sea during Beaufort Wind Force of 6 or above, as these conditions have been shown to cause motion sickness in the cattle and sheep[46]. Contingency plans in the case of poor sea conditions, and provision of venues to accommodate animals, should be the responsibility of the owner/ transporter and should be inspected by APHA.*
d. *Until further scientific research has been conducted, the maximum acceptable journey duration by sea is unknown, therefore FAWC recommends that further funding should be made available for research in establishing maximum journey limits over the sea.*

[42] J Anim Sci 2015.93:1250-1257
[43] Appl Anim Behav Sci 2017.188:17-25
[44] Vet J 2013.196:309-314
[45] Norton et al (2013). A computational analysis of a fully-stocked dual-mode ventilated livestock vehicle during ferry transportation. Computers and Electronics in Agriculture, 93.
[46] SCAHAW, 2002

e. *FAWC recommends that the concept of "neutral time" should be reviewed and that all movements over the sea should be considered as a category of journey time. Animals that are transported in livestock vessels and cassette systems are provided with water and food, and have appropriate arrangements for space, bedding, environmental control and attention but the motion of the sea is not prevented during these journeys, and they do continue 'to travel' during sea passage.*
f. *FAWC recommends that any proposed policy reform should ensure that anyone responsible (including Captain/Pilots) for transporting livestock and horses only should be required to receive suitable training as per the requirements of the proposed reformed regulation.*

102. The majority of research, as identified by the systematic review, that is carried out on the welfare of animals during transport mostly applies to road vehicles; reflecting the fact that the majority of all species of animal are transported by road vehicle.
    a. *FAWC recommends that scientific literature should be reviewed to assess if there are any welfare issues associated with transporting animals by rail or air. If so, more research on the welfare of animals during rail and air transportation should be carried out.*

Identified welfare risks during transportation

103. LAs enforce the 1/2005 Regulation relating to the health and welfare of animals that are transported. The role of the LAs is to carry out routine checks of vehicles and welfare checks on animals. LAs have a number of enforcement powers if transporters are in-breach of requirements. During stakeholder engagements, an issue identified with enforcing the 1/2005 Regulation in that LAs stated they have limited resources to enforce the Regulation, and that LAs are expected to carry out a wide range of other tasks (see paragraph 71). FAWC acknowledges Dame Glenys Stacey's report[47] on Farm Inspection and Regulation Review, which concludes that more incentive-led approaches to farming regulation must be applied. Furthermore, more flexibility, support, practical advice and guidance should be given to individual farmers, based on circumstance.
    a. *FAWC recommends that a circular approach to all journeys where feedback is provided on all long or exported journeys between the transporters and APHA. Currently, a lack of resources may mean that this is not routinely carried out. Complete feedback is required to identify reoccurring issues identified on journeys, and appropriate enforcement is applied if necessary.*
    b. *FAWC recommends that the enforcement between LAs and APHA should be better aligned and with improved collaboration so that transport and animal welfare remain*

[47] 1. The full report can be found here: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/764286/farm-inspection-regulatio-review-final-report-2018.pdf [Accessed November 2018].

a priority (similar to the recommendations put forward by the Dame Glenys Stacey report). This will require stronger liaison with LAs on improving transporter performance or APHA should impose direct action during visits on farm during inspections.

c. *FAWC recommends penalties to reduce non-compliance of a regulation should warrant further work. Finding the right penalty option (i.e. suspend or revoke vehicle approval and certificates of competence or fixed term notices) to determine which would benefit the welfare of the animals in the long term by reducing the numbers of non-compliance (as identified in paragraph 87).*

d. *FAWC recommends that more education and training, including use of agreed guidance, is applied to all those involved with the transport process i.e. transporters (see paragraph 86 and 98).*

104. The end point of the journey can significantly impact the welfare of an animal, for example if the end destination should be to a system employing a particular husbandry practice which is no longer deemed acceptable in the UK e.g. veal crate or sow tethers. The UK has banned certain farming practices that are considered to pose a serious threat to the welfare of the animal– as have the rest of the EU.

a. *FAWC recommends that no animals shall be transported to a destination where the welfare conditions are lesser or contrary to UK legislation or codes of practice.*

Species specific recommendations

105. In addition to the above generic recommendations, FAWC has provided species specific recommendations in Table 9 to Table 14 based on expert opinion and the systematic review. Note that there are no individual recommendations that have been provided for goats. Overall there is little relevant and reliable evidence on which to base policy pertaining to the transport of goats and this area requires attention[48]. FAWC would strongly reinforce the importance of not grouping sheep and goats or cattle and goats together; they are a distinctly different species and have very different requirements from other domesticated species. Increasingly, as with other farmed species, there are considerable morphological and physiological variations between breeds.

[48] Systematic review

Table 9 Species specific recommendations for sheep to be applied to any new regulation identified by FAWC and the systematic review.

Space Allowances	• *For sheep[49] to have sufficient space to adopt their preferred spacing strategy and to reduce the incidence of loss of balance, slips and falls space allowances should be calculated as: for journeys of up to 6 hours plus, the recommended empirical coefficients (and space allowances) are:* a. *shorn ewes, k = 0.026 (0.44 m^2 for 67 kg),* b. *fleeced ewes and lambs, k = 0.033 (0.56 m^2 for 65 kg, 0.4 m^2 for 40.5 kg), and* c. *shorn lambs, k = 0.029 (0.3 m^2 for 32.5 kg).*
Sea transport	• *Data on sea transport for both cattle and sheep are few, there is evidence of significant stresses relating to motion and ventilation which do not support the idea that being transported by sea could constitute a rest period.[50]*

Table 10 Species specific recommendations for cattle to be applied to any new regulation identified by FAWC and the systematic review.

Space Allowances	• *Space allowances[51] calculated according to the allometric equation A = 0.021W0.67m^2 (where A = area and W = body weight) are satisfactory for journeys no longer than 12 hours. Cattle are given sufficient space to allow them to lie down without risk, or fear of injury when space allowances are calculated according to the equation A = 0.027W0.67 m^2. Cattle with horns require 7% more space than their polled or dehorned counterparts. Cattle offered feed and drink on a vehicle, as well as space to rest, require a space allowance calculated according to the equation A=0.0315W2/3m^2.*
Fitness to travel	• *Further work on assessment of fitness to travel, impact of long journeys, recovery periods and provision of food and water to cattle is required. Due to the complexity and multi-factorial nature of transport stressors this should involve new research, as well as dissemination of existing findings[52]*
Transport Practices	• *There should be an high dependency on driver training, driver 'care' and metrics of assessment of effects during transport*

49 Systematic review
50 Systematic review
51 Systematic review
52 Systematic review

	(dirty cattle, cattle lying down (and trampled), exhaustion, dehydration, heat or cold stress)
Journey times and rest periods	• *A cattle's metabolic pathway recovers after a period up to 7 days post-transport, therefore no further transport should occur within this period.*
Long journeys	• *Before long journeys, cattle should become acclimatised to the handling and loading procedures. By pre-conditioning of calves has been shown to reduce stress before transportation.* • *Preliminary evidence suggests that vehicle design and resource (food/ water) provision can significantly improve cattle welfare, particularly for those animals undergoing long journeys, and this should be further explored.*[53]
Identified welfare risks during transportation	• *For a number of specific classes of bovines there has been very little research into the impact of transport. In particular the transport of young calves, pregnant, lactating or breeding cattle, and the specific issues around the transport of horned cattle need further work*[54]
Loading and handling	• *Cattle should be familiarised with handling and human presence in advance of journeys. This may require modification and implementation of codes of practice and new guidelines*[55].

Table 11 Species specific recommendations for pigs to be applied to any new regulation identified by FAWC and the systematic review.

Fitness for Transport	• *There is little attention applied to the movement of animals between farms or for factors that may influence the fitness for transport for example weaned pigs in cold weather. These animals may not be fit for transport but are not regulated to the same standards as animals destined for the abattoir.*
Space Allowances	• *In the case of pigs*[56] *the interaction of space allowance with ventilation and the thermal environment should be a key concern. Different space allowances are suggested for different pig groups. In general, these may be derived from the allometric equation A=kW2/3. However, information is lacking concerning the space allowances required for good welfare of piglets, feeder pigs, sows and boars in order to validate*

[53] Systematic review
[54] Systematic review
[55] Systematic review
[56] Systematic review

	allometric equations for different vehicles and thermal conditions (see Gaps in Knowledge).
Transport Practices	• *Risks are increased with collection centres. Pigs should avoid unnecessary unloading and mixing high health animals with lower health animals.* • *More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions.*[57]
Thermal conditions and Ventilation	• *Lack of heated wagons for small pigs in winter, therefore minimal bedding i.e. straw or shavings are required* • *Lack of ventilation when lorries delayed or held at abattoir before unloading. Vehicles should be designed to allow for these delays.* • *The efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures has been investigated and this approach may require further research for application in the UK.*[58]
Journey times and rest periods	• *More policing of weaner movements should be carried out.*
Long journeys	• *Pigs require continuous provision of water on long journeys.*
Sea and air transport	• *Inadequate ventilation during sea transport can lead to increased moisture and airborne contamination which can lead to serious health issues.*
Identified welfare risks during transportation	• *Extra care should be given for cull sows and avoidance of lengthy journeys.* • *Consider alternative arrangements for culls where no appropriate abattoir facility is within 8hrs travel* • *Transport of breeding boars; permit them to be mixed with sows to reduce injury and to be transported in small groups where they have been kept on the farm in such stable groups. Currently, legislation requires boars to be transported separately, but this can cause injury and distress.* • *Pigs suffer from motion sickness, so animals should be fasted both before and during transport.* • *Scientific literature indicates that transport in vehicles with leaf-spring suspension is associated with to increased skin lesions in pigs. Therefore, vehicles that are used to transport*

[57] Systematic review
[58] Systematic review

	pigs should be aware of the increased risks of bruising with leaf suspension. If possible, alternatives to leaf suspension should be considered. Vehicles should be properly equipped/ designed as not to cause injury to the animals.

Table 12 Species specific recommendations for poultry to be applied to any new regulation identified by FAWC and the systematic review.

Fitness for Transport	• *Improved training, handling and catching practices to determine if the animals are fit for transport should be applied as it is very difficult to observe fitness for travel once the birds are in a transport module.* • *Clear guidance as to who is responsible is required. The commercial egg industry insist that the responsibility is transferred from farmer to transporter at the point that birds are loaded into module drawers. We would recommend that this is adopted for all poultry systems.*
Means of Transport	• *Despite dedicated modular transport – poultry transport is susceptible to cold / hot / wet weather – and a bird fit for a journey on a 'good' day may be highly at risk during a hot / cold / wet day. These vehicles should both regulate and monitor temperature and humidity.*
Loading and Unloading / Handling	• *Catching and loading into module drawers are critical points in ALL kinds of catching/loading into modular systems. Increased levels of training should be carried out. Compulsory training for catchers should be considered.*
Space Allowances	• *Stocking density for poultry should be optimised based on actual or seasonal temperature ranges.*
Transport Practices	• *There should be a high dependency on driver training, driver 'care' and metrics of assessment of damage during transport – DOA, bruising, head trapping, fractures, dirty birds (contaminated during transport)*
Feeding and Watering	• *Birds should be transported with an empty crop. However, food should NOT be withdrawn for longer than 12 hours before the END of the intended journey*
Thermal conditions and Ventilation	• *Correct stocking density (number birds in module or chicks in box) must be selected according to expected ambient temperatures and humidity.* • *Current recommendations[59] for stocking densities for transport of poultry are adequate, however, these recommended stocking densities can predispose to heat stress in warm or hot weather*

[59] Systematic review

	and on long journeys and should be adjusted accordingly in response to meteorological predictions. Thus, limits for stocking densities of broilers in transport containers should be related to temperature. Numbers should be limited in conditions when external temperatures exceed the proposed acceptable range (e.g. > 22 ºC) and on long journeys (3-4 hours). • *In the UK (apart from chick transport), most poultry transporters are "ambient" and rely on vehicle movement for ventilation/temperature control. Therefore, a contingency plan should be considered for "vehicle standstill" (e.g. caused by slaughterhouse breakdowns and traffic disruption) should be considered.* • *By measuring the total metabolic heat production of the birds in the load, the specific heat capacity of air, and defining the acceptable rise in air temperature for the maintenance of bird welfare, then the required air flow rate can be calculated. It is strongly recommended that appropriate mechanical ventilation and temperature monitoring systems be fitted on all vehicles for transporting poultry.*[60]
Journey times and rest periods	• *Any journey above 4 hours increases the welfare risk as it increases the likelihood of increased mortality, therefore more work is required to determine the maximum journey duration of broilers, turkeys and laying hens.*
Long journeys	• *Young (newly hatched) chicks are unable to effectively thermoregulate. Exposure to temperature stress, especially from long journeys, might be measurably demonstrated by rectal temperatures and/or by weight loss. Temperatures and humidity should be monitored and recorded.* • *More research is required to determine the optimum temperature ranges in poultry.* • *A maximum journey time for chicks is 24 hours deemed acceptable in the first 72 hours post-hatching.* • *The definition of a maximum journey time to slaughter for modern broiler chickens is required.* [61]
Identified welfare risks	• *Spent hens are fragile animals that have undergone immense physiological strains. Therefore, long journeys should be minimised as much as feasibly possible.*

[60] Systematic review
[61] Systematic review

during transportation	• *Heat or cold stress are a particular concern for all poultry. Therefore temperature and humidity ranges for these animals should be determined.* • *Impractical to feed and water chicks/ poultry in crates, it is therefore suggested that the journey times are revisited.*

Table 13 Species specific recommendations for horses to be applied to any new regulation identified by FAWC and the systematic review.

Means of Transport	• *Partitions and individual travel except mares with their foals. Young or non-halter broken horses may become stressed when they are individually partitioned [further research is needed to determine the optimum age horses can be separated during travelling].*
Fitness for travel	• *Horse welfare in transport could be improved by the adoption of best practice in assessment of fitness to travel, loading and penning to avoid mixing and aggression, journey time and driver responses[62].*
Space Allowances	• *For horses[63] it is recommended that space allowances should be given in terms of kg/m^2 instead of m^2/animal where animals are likely to differ significantly in weight or body condition. For handled horses (except for mares with foals), animals should be transported in individual pens to prevent aggression.*
Transport Practices	• *Owner/keeper have limited driver requirements if vehicle falls below 3.5t (no CPC required), no vet checks on loading or unloading of horses. Anyone transporting animals should be trained.*
Thermal conditions and Ventilation	• *Ventilation needs to be optimised in transporters by increasing the level of flow. More work is needed to find the optimum temperatures for travelling.*
Long journeys	• *Horses should not be transported longer than 24 hours during hot weather conditions and without water. Journeys over 28 hours lead to fatigue, it is suggested that a rest stop every 4.5 hours with electrolytes in the water.*
Identified welfare risks during transportation	• *Horses prefer to travel aligned with direction of movement for all modes of transport.* • *Registered horses should conform to the same regulatory standards as non-registered horses.*

[62] Systematic review
[63] Systematic review

Table 14 Species specific recommendations for <u>dogs</u> to be applied to any new regulation identified by FAWC and the systematic review. [64]

Transport Practices	• *No driver training/ CPC/CoC requirement even for couriers. No vet checks at arrival or loading. Anyone transporting animals should be trained.*
Identified welfare risks during transportation	• *Dogs should not be sedated on any journey.* • *Maximum journey times should be introduced.* • *Compliance with IATA regulations for animals transported in containers.*

[64] The RSPCA have commissioned a report on the welfare of dogs during transport and will produce guidelines based on the results of their report. This report will be published during 2019.

PART 5: THE WELFARE PRINCIPLES TO BE APPLIED TO THE TRANSPORT OF ANIMALS

106. The conclusions and recommendations in part 4 of this opinion have identified a number of omissions in understanding of species specific and particularly subgroup-specific (young, juvenile, adult or end of life, weight, shorn/ unshorn and breed) animal welfare needs during transport. FAWC have proposed a generic list of principles which apply to all animals that are transported, and which should be considered whenever any animal is moved, acting as principles against which any movement being planned or undertaken should be considered.

107. The unique nature of transportation of animals leads to transport specific welfare concerns. The Five Freedoms can be readily applied, with some further refinement, to transport and we propose 10 principles in relation to animal transportation. Application of these principles would help to ensure that the welfare of the animal around transport is given due consideration, and that welfare is maintained as a consideration throughout the whole of the transport process.

108. The principles listed below all have the same 'weight' and should not be ranked. The principles of animal welfare during transport for any one journey are as follows:

I. **The three "R's" should be applied to transportation.**

   a. Replacement: If any measure that can lead to replacement of the transport of live animals is practical, then it should be applied. For example; can meat-only trade, or artificial insemination, replace the transport of animals?

   b. Reduction: If any measure can be applied to the proposed journey that will result in a reduction in the number of animals, the duration, or the distance of the journey then these should be applied. For example; could animals be finished or slaughtered at a premises which is closer than the original premises?

   c. Refinement: If any measures exist that can be applied to refine a proposed journey, and are practical, then they should be applied. For example; the means of transport should consider, age, sex, size, weight, coat length and health status of the animal – and transport methods should be used which best meet the physiological and mental needs of the animal.

II. **All persons that are involved in the transport of animals have a responsibility to ensure the welfare of those animals. Anyone with these responsibilities should be trained, and shown to be competent.**

III. **The number of loading and unloading events for any one animal must be minimised.**

IV. **No journey should be undertaken where the likely negative welfare impacts to the animal cannot be justified. The individual journey should be planned to consider the physiological and psychological needs of that animal, or species, or group. Planning should include consideration of loading, unloading, journey stops and rest stops.**

V. **The animal, or animals, must be fit for the intended journey, and the animals must be in a fit state at the end of the journey.**

VI. **There must be a contingency plan in place for reasonably foreseeable circumstances.**

VII. **Transport should match the species-specific requirements of the animal[65].**

VIII. **The competency requirements of the transporter (driver, captain, pilot, etc.) must match those of the vehicle, the animals, and the distance, type and nature of the journey. Ongoing competence should be demonstrated by undertaking training that must be relevant to the welfare of animals and use of metrics of ongoing performance.**

IX. **The destination 'outcome' must conform to regulatory requirements that will continue to protect the welfare of the animals at a level not below that of the UK. This will ensure that the standards for the animal at the destination (for example slaughter conditions or husbandry conditions) will be equivalent to, or better than those for an animal in a similar situation in the UK.**

X. **There must be a robust audit/ inspection of animal welfare during transport, and accompanying appropriate penalties (either through assurance or legal penalties) for failure or breach of the duty of care. Clear communication and feedback throughout the supply chain should be practised to maintain attention to animal welfare throughout all stages of transport.**

[65] To consider some of the requirements: breed, sex, weight, young, juvenile, adult or end of life young, shorn/unshorn

<u>APPENDIX A:</u> SCOTLAND'S RURAL UNIVERSITY COLLEGE AND UNIVERSITY OF EDINBURGH SYSTEMATIC REVIEW

A review of the evidence on welfare aspects of the transport of live animals

Defra Project AW0821

M. A Mitchell, J. Martin and P.J. Kettlewell

September 14th 2018

(revised 21/03/18)

Contents

List of Figures

Executive Summary

1. The welfare of animals in transit is a significant cause of public and political concern. Animals can be subjected to a variety of different stressors, such as thermal loads, motion, vibration, acceleration, impact, fasting and the withdrawal of food and water, behavioural restrictions, social disruption and mixing with unfamiliar animals, noise and air contaminants.
2. Currently the movement of UK livestock is subject to European Law (EC 1/2005), which regulates journey times, rest periods and vehicle design. With the planned withdrawal of UK from the EU, new UK legislation may be required which should be based on sound scientific evidence.
3. The aim of this project is to critically review the scientific evidence relating to the welfare of commercial livestock (cattle, pigs, poultry, sheep and horses) during transportation including pre-journey preparation, handling and loading and post-journey procedures.
4. More specifically the objectives of the project are to assess the effects on welfare of long journeys i.e. intra-community trade and export journeys; consider the impacts or effects of transit through markets, assembly centers and control posts; identify knowledge gaps and high risk scenarios for poor animal welfare; and provide insight into possible improvements in practice and guides to best practice.
5. The review covers all aspects of the transportation process including the impacts of journey times, stocking densities, thermal conditions and ventilation regimes and practices, weather and season, vehicle and container design and operation, species, age and physiological status of the animals.
6. A systematic review (SR) approach has been selected as this provides a more rigorous approach to reviewing the literature, and has examined material published in the scientific literature in the last 50 years (1st January 1968 to 31st March 2018) relating to animal transport and welfare. This has been supplemented by information from the 'grey' literature (such as trade publications and NGO material) and published documents from EFSA, DG-SANCO and Defra.
7. The SR returned 4350 publications over the last 50 years, which was filtered to 699 in Phase 1 (removal of papers which did not meet the eligibility requirements, e.g.

reviews, species not in scope etc), and 328 in Phases 2 and 3 (assessment of quality and allocation to topics), on which the SR is based.

8. Of these 328 the majority of papers are on pigs and poultry (89 and 81 respectively), followed by cattle (50 papers), sheep (38), equidae (35), multiple species (16), goats (15), dogs (1). Two papers on transport design and 3 engineering studies were also included.
9. The vast majority of papers (94.5%) cover road transport, 2.4% deal with sea transport (generally of cattle and sheep) and 1.8% deal with air transport (almost all of horses).
10. Significant knowledge gaps (defined as no identified scientific papers on the subject) were identified for almost all species when considering the welfare of animals at market, and for the transport of entire males. In addition, only limited research (<5 papers) has been conducted in breeding bulls, dairy cattle, ducks, ducklings, layer hens, layer pullets, turkeys, turkey poults, piglets, sows, weaners, boars, rams, donkeys/mules, foals and dogs for all welfare criteria.
11. *Recommendation 1: Further research is required on the welfare of animals at markets. In addition, research into the welfare of animals other than the slaughter population (e.g. breeding animals, young and very young animals) in transit, and for turkeys and dogs is required.*

Transport of Cattle

12. Particular issues associated with the transport of cattle that have not been well researched are: the additional space required, and risk of injury posed, by transport of horned cattle; space requirements for the transport of pregnant cattle; welfare risks of transporting young calves, which will require special feeding often as frequently as every 8-9 hours; and milking of lactating cattle in transit.
13. Animals least fit for transport suffer the greatest losses in terms of welfare and meat quality while market ready animals in good condition appear to have fewer issues. However, only half of drivers who assess fitness to travel were able to

answer questions on fitness to travel correctly, and a third expressed frequent doubt over the fitness to travel of some cattle.

14. Loading of calves can be improved by training calves to load at weaning, which results in lower heart rate, cortisol and metabolites in trained calves when loaded at older ages. Pre-journey handling (or conditioning) also improves the ability of calves to withstand the stressors of transport. For all ages, low stress handling at the time of transport for slaughter is essential.
15. Transport is a complex and compound stressor, composed of the stressors associated with loading and unloading, journey duration (the amount of time the animal spends on the transporter, whether moving or not), distance the animal travels, their physiological state before the journey, access to feed and water, ability to rest and the thermal environment. There is little evidence that journey duration, per se, has a detrimental effect on animal welfare, rather that compromised welfare is due to the associated negative effects of food and water deprivation, inability to rest and thermal conditions.
16. Cattle can be transported for long journeys with no differences in the behaviour or physiology of cattle being found between transport of 14 and 31 hours. However, higher mortality has been seen when cattle travelled for greater distances and in warmer seasons (higher in spring and summer than autumn and winter).
17. Access to feed and water, rest and the thermal environment are important considerations, which can adversely affect cattle welfare, and are exacerbated with long journeys. Cattle are seen to lie down after 24 hours of transport, when there is sufficient space to do so, and require more than 24 hours in lairage with food and water to recover.
18. Lack of access to feed and water on long journeys, or those involving a sea crossing, are suggested to be the main cause for welfare concern. Beef cattle can lose up to 7% of body weight during a sea crossing (from Ireland to France, an average of 23 hours on the ferry), which takes up to 6 days to be recovered. Twenty-four hours in lairage with food and water allowed a substantial recovery in physiological, haematological and immunological variables.
19. Sea transport may also induce marked changes in the thermal microenvironment (heat, humidity, airborne contaminants) which can induce heat stroke, respiratory

disease and trauma. Improvement in truck design or a better understanding of the impact of these additional stressors is required.

20. Current EU regulations require rest stops on journeys of >8 hours to allow food and water. Rest stops alleviated some physiological parameters associated with withdrawal of food and water in cattle, but not in newly weaned calves, and were more beneficial if cattle had increased access to feed when at a rest stop.
21. Where cattle were transported through markets a higher incidence of carcase bruising (4% of animals) was observed than when cattle were transported directly from farm. Poor handling facilities and inappropriate use of goads are also frequently seen at markets.
22. Road conditions and standing orientation (perpendicular compared to facing forward) influence the degree of vibration experienced in transport. Improved truck designs may help to mitigate these effects, especially for long journeys.
23. Stressors associated with transport, in newly weaned beef calves, are associated with immunosuppression, reduced appetite, initial weight loss and greater vulnerability to disease, particularly respiratory disease.
24. Temperature and humidity index interacts with stocking density and season/ambient temperature in transported cattle. Although in most studies animals ended their journeys in good condition with only transitory changes in physiological markers for stress, effective temperature in the vehicle, and thermal stress were key risk factors for mortality in transit and post transport disease.
25. A range of different biomarkers have been used to assess welfare in cattle in transit. These include acute phase proteins, serum antioxidant capacity, measures of circulating metabolites (albumin, globulin, urea, total protein, creatinine kinase, β-hydroxybutyrate), leukocyte numbers and proportions, immune markers (lymphocyte proportions and subsets), hypothalamic-pituitary-adrenal axis markers (cortisol, DHEA, cortisol:DHEA ratio), other endocrine biomarkers (testosterone, progesterone, T3 and T4). Some of these (e.g. core body temperature, heart rate, N:L ratio) show meaningful changes with qualitative behavioural assessment associated with decreased welfare during transport.
26. *Recommendation 2: For a number of specific classes of bovines there has been very little research into the impact of transport. In particular the transport of young*

calves, pregnant, lactating or breeding cattle, and the specific issues around the transport of horned cattle need further work.

27. *Recommendation 3: Further work on assessment of fitness to travel, impact of long journeys, recovery periods and provision of food and water to cattle is required. Due to the complexity and multi-factorial nature of transport stressors this should involve new research, as well as dissemination of existing findings (e.g. Best Practice Guidance).*
28. *Recommendation 4: Preliminary evidence suggests that vehicle design and resource provision can significantly improve cattle welfare, particularly for those animals undergoing long journeys, and this should be further explored.*

Transport of pigs

29. Hazards characterised as serious for transported pigs include: inadequate ventilation, insufficient space allowance, transport duration, lack of sufficient water during transport, incorrect handling during loading, poor fitness prior to transport, and introduction of pathogens before and during transport and the inappropriate application of resting periods during transport.
30. Pigs feel more relaxed and less stressed when handled by staff who understand pig needs and behaviour. Well-trained workers are able to load and unload pigs in a relatively short time without stress, thus minimising the risk of injury, slipping and falling. In addition, good handling has a positive effect on the quality of the carcass and meat.
31. There is general agreement that animals that are non-ambulatory, severely injured, sows in the last 10 percent of pregnancy, sows with uterine prolapse and very thin animals are not fit to travel.
32. Pigs transported without water are more severely affected than transport without food, and the recent research supports EC 1/2005 in recommending that pigs should have continuous access to water when travelling.
33. During long journeys animals will get tired and resting periods are required. In control posts and other places where animals are offloaded, pigs should be housed

comfortably with appropriate space allowance, in good thermal conditions and allowed to drink and eat according to the expected fasting period. Lairage of greater than 4 hours without food causes alterations in metabolism which suggest reduced welfare.

34. Mortality increases with journey length, with best pig survival, and least weight loss, occurring when journeys are less than 100 km, compared to journeys of 300 km or more. Longer journeys are associated with behavioural and physiological indicators of stress and physiological disruption (especially after 18 hours of transport), poorer meat quality, greater weight loss and a linear increase in markers for muscle fatigue (creatinine kinase). Pig welfare decreases when pigs are transported at temperatures below 5°C or above 20°C.
35. Newly weaned piglets are more vulnerable than older animals, requiring more precise temperature controls and warmer conditions than older pigs (ideally between 25-30°C). Transport exacerbates the effects of early weaning and the evidence suggests that transport of newly weaned piglets should not exceed 12 hours.
36. *Recommendation 5: More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions.*
37. *Recommendation 6: The definition of stocking densities or space allowances for pigs in transit should be revisited. The calculations should be based upon pig body weights (allometrics) and take in to account any special requirements for the type of animal or for a procedure (e.g. feeding and watering). The specified space requirements for weaner piglets should be re-examined.*
38. The importance of using integrated indices of thermal load has been demonstrated, which combines humidity with temperature and change over time. Pigs are more stressed with higher temperature (greater than 20°C) or enthalpy time derivatives, and this measure could be used as a more sensitive index of welfare risk than absolute temperature or relative humidity.

39. *Recommendation 7: The efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures has been investigated and this approach may require further research for application in the UK.*

40. Pigs appear in better welfare after a period of food withdrawal of only 1 hour. However, this can be a risk factor for travel sickness if they are transported with a full stomach. Pigs can become very travel sick, especially on short journeys which are rough and where there is insufficient space or substrate for pigs to lie down.

41. Mixing pigs at loading, particularly of conventionally reared pigs, leads to more aggression and less lying during transport. Outdoor pigs are less aggressive than indoor reared pigs, and had lower incidence of damaging skin lesions from fighting.

42. Average mortality in 739 journeys to slaughter in 5 EU countries was 0.11% with 0.36% of pigs being injured in transit. The biggest risk factors for mortality were temperature, not fasting prior to transport and rapid loading speed.

43. *Recommendation 8: Transport stress may be reduced through a vehicle suspension system that provides a much smoother ride during transport, and consequently is less aversive to pigs. This should be examined in more details in terms of full elucidation of stress responses associated with vibrations and ride type.*

44. Assessments of pig welfare have used a number of biomarkers, including responses of Acute Phase Proteins, heat shock proteins, growth hormones, cortisol, glucose, creatinine phosphokinase, total protein and changes in circulating neutrophil to lymphocyte ratio.

45. When considering the welfare of pigs in transit, it is important to also include the handling of animals before, during and after transport as a critical factor that can affect pig welfare and should be assessed as part of an integrated assessment scheme.

Transport of sheep

46. The welfare of sheep in transit can be affected by the new and unfamiliar environment, movement restrictions due to confinement, vibrations, sudden and

unusual noises, fitness of livestock, mixing with other animals, temperature and humidity variations together with inadequate ventilation and feed and water restrictions. The effects of all these factors are influenced by the experience and condition of the animals, the nature of the journey, and the duration of transport.

47. In order that animal welfare can be kept at a high level during transport, it is important that all of those involved in the transport and related operations are properly informed about the animals and how to assess their welfare. Checking the animals before loading will reduce the risk of sending animals for transport that may not survive the journey, or suffer serious welfare consequences. Careful planning of journeys and ensuring the suitability of appropriate vehicles is important, with emphasis placed on compartments height and the use of partitions.

48. Long journeys, should be avoided wherever possible and much better conditions are needed if journeys are long. Vehicles should be driven carefully and sudden turns and braking should be avoided, especially on roads with sharp bends or at right angle turns into other roads. Thermal conditions and ventilation management are important to reduce the effects of heat stress on sheep.

49. Lambs transported for 9 hours or less had lower stress, whereas healthy adult sheep, transported under favourable conditions, can tolerate road transport durations of up to 48 hours without obvious changes in physiological responses. However, these animal may show behavioural changes associated with increased motivation to eat, drink or lie down. It is difficult to find data to support prescribed maximum journey times, applicable to all transport types and conditions and more emphasis should be placed on the quality of the journey rather than focusing exclusively on duration.

50. Slaughter lambs or adult sheep can tolerate withdrawal of water for up to 22 hours at cool temperatures, without showing an increase in drinking when water is provided. However, suckling lambs are more sensitive to dehydration after only 5 hours.

51. Healthy adult sheep can cope with food deprivation for 2-3 days by mobilizing body reserves, and withdrawal of animals from pasture up to 30 hours before transport can occur without metabolic depletion, although the animals may experience the adverse consequences of hunger.

52. Loading and initial transport of sheep causes the greatest change in stress responses, compared to later in the journey. Handler experience and attitude, suitability of handling facility design and familiarity of the animals with handling can all improve the experience for sheep.

53. Sheep provided with 1 m^2 or above in transit were seen to stand close to, but not touching their pen-mates, bracing themselves against the motion of the vehicle by spreading their feet, not by leaning on their pen-mates. They were also seen to lie in transit at higher space allowances. This led to fewer losses of balance, slips and falls than higher stocking density.

54. Recommendation 9: There is strong evidence that stocking densities or space allowances for sheep and lambs should calculated according to an allometric equation relating size to body weight. As current minimums in legislation do not allow sheep to use preferred balance strategies optimum allowances should be confirmed by appropriate research and modelling.

55. Mortality from heat stress during road transport rarely occurs in sheep, though it is essential that adequate ventilation is maintained on-board the vehicle (e.g. reducing the amount of time that the vehicle is stationary).

56. The quality of the journey experienced by sheep in transit was greatly affected by driving style and driving events and consideration of these factors should be key in driver training an assessment.

57. Long-distance sea transport exposes livestock to similar stressors to those experienced during road, rail or air transport; however, there are few independent peer-reviewed studies of the increased risk of cumulative stress during the extended transport period.

58. *Recommendation 10: Although the data on sea transport for both cattle and sheep are few, there is evidence of significant stresses relating to motion and ventilation which do not support the idea that being transported by sea could constitute a rest period.*

Transport of goats

59. Goats preferentially travel parallel to the direction of travel, and most falls occurred due to driver behaviour, e.g. rapid acceleration, braking or cornering. Ensuring a

calm and measured driving style is key to avoiding falls and excessive effort for postural stability and that this will reduce both stress and injury and will improve carcase quality in slaughter goats.

60. *Recommendation 11: Overall there is little relevant and reliable evidence on which to base policy pertaining to the transport of goats and this area requires attention.*

Transport of poultry

61. The welfare of transported birds can be affected by catching and handling before transport, ventilation, temperature, truck microclimate, food and water restriction, vibration, space restrictions, noise and pollutants. These can differ when transporting day-old chicks or end-of-lay hens or broilers.

62. The first journey of young chicks is a major threat to welfare, and to the future productivity of the bird. Ventilation is particularly important to prevent cold stress and mortality.

63. For broilers and end-of-lay hens handling and crating can be very stressful, and result in broken bones, bruising and haemorrhage. In addition, thermal load is a major factor in deaths during transit, inducing stress, pathology and eventual death.

64. Fitness to travel in broilers can be determined by inspection of preloading lameness, illness, hock burns, foot-pad dermatitis, lesions, physical defects, cleanliness and cachexia. Birds considered unfit on this basis had higher indicators of post transport stress than birds deemed fit to travel.

65. Increased journey times for chicks are associated primarily with physiological responses indicative of food and water deprivation, and can induce slower growth and body weight for up to 21 days post transport.

66. Although newly hatched chicks have a yolk sack, which can provide food and water, this is largely depleted within 24 hours of hatch, and dehydration and undernutrition are major causes of mortality during and after transport in chicks.

67. *Recommendation 12: The available evidence suggests that the maximum journey time of 24 hours for newly hatched chicks may still be appropriate based on available knowledge of yolk sac reserves and resource utilisation. However, longer*

journeys do cause greater physiological stress, which may relate to the inability of the chick to cope with temperature changes, and future research is required to specifically address this issue.

68. Neonatal chicks do not possess a fully developed effective homeothermic mechanism, and consequently are vulnerable to the detrimental effects of thermal loads and fatigue and dehydration.
69. Older birds are also vulnerable to dehydration from panting to dissipate heat, and because food and water is withdrawn before transport. Poultry also cannot be fed or watered in transit and thus journey times must be shorter than for other meat species.
70. Average mortality in transit is 0.1-0.6% for broilers, 0.38-1.0% for hens, 0.14-0.27% for turkeys, 0.06-0.1% for ducks and 0.056% for geese. Significant contributors to mortality are journey length, stocking density in compartments and ambient temperature/season of transport. Transport of up to 4 hours is estimated to increase mortality 10 fold over non-transported birds, and 19 fold for journeys over 4 hours.
71. *Recommendation 13: The definition of a maximum journey time to slaughter for modern broiler chickens is required.*
72. Rest periods for poultry are not recommended and can be counter-productive. It is not feasible to offer food or water, they cannot be effectively inspected and the reduction in airflow when a passively ventilated vehicle stops can cause a rise in temperature and is a risk factor for hyperthermia and dehydration.
73. Birds can be caught at destocking by the body, one or both legs or be mechanical catching machines. Although the body capture would be preferable, birds are generally caught by the legs. Machine capture can reduce bruising, bone breakages and dislocations compared to manual capture and improves with experience of using the device, unlike manual capture.
74. Holding animals in lairage causes an increase in deep body temperature, and depletion of muscle glycogen. It is therefore recommended that birds are killed immediately on arrival at the slaughterhouse, or within 1 hour.
75. The localised on-board vehicle micro-environment for chick transporters are determined by the prevailing climatic conditions, the addition of heat and water

vapour to the load space from all sources including the bio-load (chicks) and the ventilation rate and distribution. These have received less attention that other transporters and further research is required.

76. Air transport of chicks is becoming increasingly common, but these complex journeys structures can increase time without access to food or water, and mortalities are closely related to overall journey time.
77. Changes in temperature and water pressure in air transport increases the risk of dehydration and thermal stress. Food and water can be provided for chicks engaged in long distance transport by provision of hydration gels, but further research is required to improve the welfare of chicks transported by air.
78. There is little published data on stocking density or space allowances for transported poultry. Theoretically, the minimum space required by a bird can be calculated from Area (m^2) = 0.021 weight (kg) $^{0.67}$, and thus a bird weighing 2.0 kg needs 0.0334m^2, equivalent to a stocking density of 59.9 kg/m^2, and a bird weighing 2.5 kg needs 0.03889m^2, equivalent to a stocking density of 64.4 kg/m^2.
79. Stocking at high density is associated with physiological indicators of poor welfare, and an increase in DOA. This is particularly important in hot weather when stocking density must be reduced to prevent build-up of heat and humidity by increasing the opportunity for air to circulate.
80. There is little clear evidence for acceptable crate heights as low crates increase stress responses and panting, whereas higher crates, where birds are able to stand, are associated with potentially damaging behaviours.
81. Thermal stress may be the major source of welfare compromise during the transportation of newly hatched chicks. Evidence from scientific studies suggest an optimal temperature-humidity range of 24.5-25.0ºC and 63-60% RH for the transport of chicks at commercial stocking density. If the temperature and humidity inside a transporter can be maintained at these levels then chicks can be safely transported for at least 12 hours.
82. For broiler, turkey and hen transport location in the transporter can have a significant effect on welfare. Birds pant to reduce temperature by evaporation from the respiratory tract. However, this is ineffective at high humidity and with poor air

flow and ventilation. Thus, birds in the centre of a load are at risk of hyperthermia and dehydration, whereas birds on the outside of a load may become cold and wet.

83. In hot temperatures vehicle movement is an important source of air flow and cooling. When vehicles are stationary an increase in ambient temperature can occur, which increases the risk of hyperthermia and mortality. In cold temperatures birds may become hypothermic, especially if they are poorly feathered, wet or dirty, and are subject to the effects of wind chill.

84. The microclimate in the transporter is heterogeneous, with highest temperatures in the upper front central region. Even on relatively cool days in the UK, localised temperature in this area can be 25-26°C and core temperatures of >30°C and water vapour densities >20gm^{-3} have been reported in the UK. Thus even in low environmental temperatures birds can be at risk of heat stress and poor welfare.

85. Recent studies under extreme low temperature conditions confirm that heterogeneity in temperature on transporters can mean that birds can experience both extreme hypothermia and hyperthermia on different locations in the same transporter. Differences in temperatures across different locations varied by as much as 30-40°C.

86. Holding birds on the transporter in lairage may exacerbate heat stress as the micro-climate is often poorly controlled. This can lead to range of outcomes affecting bird welfare and meat quality.

87. In passively ventilated vehicles ‘hot spots’ are present towards the front of the vehicle and ‘cold spots’ to the rear and outer areas, especially if birds become wet. With curtains or closed-sides the impact of poor air flow on bird welfare is increased, therefore mechanically ventilated transporters are required to improve air flow.

88. *Recommendation 14: By measuring the total metabolic heat production of the birds in the load, the specific heat capacity of air, and defining the acceptable rise in air temperature for the maintenance of bird welfare, then the required air flow rate can be calculated. It is strongly recommended that appropriate mechanical ventilation and temperature monitoring systems be fitted on all vehicles for transporting poultry.*

89. Average mortality of end-of-lay hens when transported to slaughter in UK is 0.27%, with increased mortality risk with longer journeys and low external temperatures. Other studies confirm that spent hens are at greater risk of hypothermia than hyperthermia in UK, particularly those birds located on peripheral locations.
90. For turkeys, average DOA was 0.15% and the risk of mortality increased with longer journeys. Highest mortality was seen in the summer and heat stress seems a more important risk factor for mortality than cold stress in turkeys.
91. A range of biomarkers and other measures have been applied in poultry transport studies. These include all the traditional stress biomarkers as well as novel indicators such as the expression levels of circulating micro-RNAs (miRNA), activity of the immune system e.g. CD8+ cells and antibody production.
92. The published data, at this time, do not support the proposal that an increased metabolic rate in modern, rapidly growing lines of broilers will result in a more rapid depletion of reserves of energy, substrates and water that will compromise the welfare of the birds in the currently prescribed periods for transportation. There is also little evidence relating the physiological and metabolic status of the post-hatch chick to bird welfare.
93. *Recommendation 15: In this context the measurement of circulating levels of metabolites and appropriate hormones and other biomarkers would usefully inform assessment of metabolic, physiological and stress status of newly hatched chicks. This approach would best define the upper physiological limit for a period of inanition post-hatch.*

Transport of horses

94. Horses in transit are subjected to a number of specific hazards for good welfare including: poor inspection and assessment of fitness to travel, lack of appropriate penning, poor watering provision, long journey duration and poor driving and/or transport conditions.
95. Horses in transit are often unbroken and unaccustomed to being handled or led. They should be distinguished from horses that are broken as unhandled horses will have little or no prior experience of transport and are likely to be considerably more stressed.

96. Transported horses are at risk of dehydration. Transporting healthy horses for more than 24 hours without water in hot weather will cause severe dehydration. Transport for more than 28 hours even with periodic access to water will likely be harmful due to increasing fatigue.
97. Horses that are lame or injured were reported to be transported for slaughter frequently in EU, and the incidence of disease and injury found at arrival increases with long distance transport.
98. Studies in Canada and Australia where horses underwent long journeys report health problems in 7% and 3% of horses respectively, and 0.24% mortality was reported in the Australian study. Most health issues were seen in journeys of over 20 hours.
99. Ventilation in a horse transporter was inadequate when compared to recommendations for stabled horses, at any speed and thus improved ventilation is required in transporters for horses.
100. Horses adopt a braced position when travelling and spend considerably less time eating when in motion than when the transporter is moving. The data suggest that horses can become fatigued on long journeys.
101. There is good evidence that horses prefer to travel facing backwards away from the direction of travel and find it easier to maintain balance in this orientation.
102. Injury during transport is relatively common in horses, particularly those travelling to slaughter, associated with driver behaviour, vehicle design and mixing of animals of different weights and sexes leading to aggression. Improvements in monitoring and training could reduce these welfare issues.
103. Studies of sport horses recommend that on long journeys horses have a rest stop every 4 hours of at least 30 minutes duration during which they are provided with water, and that they be allowed exercise after 18 hours. It is suggested also that horses should be prepared for long distance transport by pre-journey administration of electrolytes and antioxidants (vitamins E and C and selenium). The efficacy of this strategy requires confirmation.
104. *Recommendation 16: Horse welfare in transport could be improved by the adoption of best practice in assessment of fitness to travel, loading and penning to avoid mixing and aggression, journey time and driver responses.*

105. Horses appear able to tolerate air transport very well when travelling in suitably designed accommodation. Loading, take-off and landing, and turbulence induced some behavioural and physiological indicators of anxiety.

106. A number of physiological indicators have been used to assess horse stress and welfare in transit. Thyroid hormones, salivary and plasma cortisol and ACTH (and metabolites in faeces), heart rate and heart rate variability, and oxidative stress measures suggest that horses do find transport stressful, particularly long distance transport.

107. Assessment of the welfare of horses arriving in Italy has been conducted using a welfare assessment tool. This suggested that ramp angle and flooring affected slips and falls, and that horse behaviour was related to the type of handling procedure used.

108. Horse behaviour during transport has been shown to affect clinical and respiratory outcomes. A higher amount of stress related behaviour was associated with higher physiological stress and respiratory tract inflammation and bacterial contamination.

Other review processes

109. In addition to the scientific literature examined during the review process, areas of welfare concern identified by the Defra expert/stakeholder group (2008), EFSA expert opinion (2011) and the DG-SANTE project 'Good practices for animal transport in the EU' (2017) were examined to provide a comprehensive overview of the potential knowledge gaps.

110. A priority areas identified in the previous review processes has been the disparity in the social regulations relating to drivers hours and the journey times presented for livestock in current regulations (e.g. EC 1/2005). Harmonisation of the driving regulations with animal welfare in transport regulations is desirable but there is no research to determine if the various proposed travel time combinations that would facilitate harmonisation have any positive or negative impacts on animal welfare.

111. Whether time on board a ferry can be designated as rest and whether the rest on-board ship is to be rest time, neutral time or part of journey time still requires clarification. The thermal environments experienced during ferry transport is poorly understood as there a very few publications in the field. Research is required to better understand optimum ventilation strategies for vehicles on-board ferries.

112. There has been very little research conducted into the welfare of animals at markets and how markets affect the welfare of animals undergoing complex journeys.

113. The vast majority of work has focused on the slaughter population, and therefore new research is required to address the welfare needs of very young animals (e.g. temperature requirements of calves and piglets) and the older animals, such as cull sows and spent hens.

114. Head space requirements, or clearance above the withers, for cattle, pigs and poultry is not clear and further research is required to determine best practice.

115. Long journeys for young calves remains a welfare concern with a number of unanswered questions that require research. These include whether the lower age limit for transport is too young, whether the current 9-1-9-24 structure for journeys adequately protects calves, and whether a maximum limit of 9 hours should be introduced.

116. In addition how well calves can be supplied with food and water during transit requires further research. For example: do calves drink on board with an unfamiliar nipple system, should calves be provided with food/water during the mid-journey break and how, and should feeding and watering practices be more strictly prescribed for calves on long journeys?

117. The maximum stocking density for pigs is presented as a single figure (235 kg m^{-2}) on an area basis and primarily applies to pigs of around 100kg body weight. Clearly if this basis was used for smaller e.g. weaner pigs then the number of pigs per unit area would become problematic. Research in the area might better inform future policy, advice and legislation as to the optimum stocking densities (space allowances) for pigs over a wide range of body weights.

118. Mechanical ventilation regimes and throughputs should be further investigated to ensure that ventilation will be adequate to ensure thermal comfort in large pigs on stationary vehicles under hot weather conditions.

119. Current recommendations state that pigs should not be fed less than 6 hours before transport, based on limited published information concerning "motion sickness" in pigs. However, conflicting research suggests that pig welfare is better after only 1 hour of food withdrawal. Further research in this area would help resolve this issue.

120. Pre- and post-journey factors, such as farm type, housing (indoor on slats or outdoor for example), and abattoir standing time may have a bigger impact on welfare in transit than journey time per se. Further research, in all slaughter species, is required to understand these effects.

121. Poor driving style can impact on the welfare of all transported animals and this has been highlighted for sheep, which often stand during transport. Validation of proposed monitoring devices (based on vehicle accelerometers) for animal welfare would be required if these are to be used.

122. Although space allowances of sheep can be calculated from allometric equations, the impact of inadequate floor space and head space for ventilation and thermal control on long journeys on heat stress requires further research.

123. The risk of dehydration, and whether and how water can be provided on board vehicles for sheep has not been addressed in the published literature.

124. Research into the welfare of animals in markets is generally lacking, including water provision, and research into motivation to drink at markets under a range of environmental and transport conditions is required.

125. There is currently no definition of 'long journeys' for poultry in EC 1/2005 and thus no specified thermal limits for transport. Further research is required to establish thermal comfort zones for laying hens and end-of-lay birds.

126. The available research into the journey times for transport of newly hatched chicks suggests that this may be compatible with good chick welfare based on assessment of yolk sac resource utilisation but further research could confirm this.

127. Design innovations to improve ventilation and thermal micro-environment control in chicks have been developed and further research to understand if these can improve chick welfare is required.

128. Methods to provide food to chicks and water to poultry in transit could improve welfare and research to develop optimal methods would facilitate this.

129. Evidence suggests that horses do not cope well with long journeys, and good quality research to establish upper acceptable limits for horse transport is required.

130. it has been suggested in the literature that there is great variation between breeds in thermal requirements. The thermal comfort zones of horses, and the impact of humidity, are not known and this gap should be addressed through research.

131. More comprehensive research into the welfare of horses travelling in different placing configurations is required to develop recommendations for their transport.

A review of the evidence on welfare aspects of the transport of live animals (AW0821)

Tender Reference: 24627

Introduction

The welfare of animals in transit continues to be a matter of public and political concern. In view of the potential withdrawal of the UK from the European Union and associated implications for the possible review and revision of legislation it is important to ensure that current legislation and any future amendments thereto are based on sound science. Indeed the UK Government is committed to “control the export of live farm animals for slaughter” once the UK leaves the EU. The implementation of any control on livestock export must comply with WTO rules on trade and therefore must be based on robust evidence. Any future policy in these areas must be informed by underpinning science.

During transportation animals will be exposed to a number of potential risk factors for poor welfare including thermal loads, motion, vibration, acceleration, impact, fasting and the withdrawal of food and water, behavioural restrictions, social disruption and mixing with unfamiliar animals, noise and air contaminants. These can be exacerbated by aspects of the journey structure such as journey duration, journey complexity (e.g. loading and unloading, control posts), truck characteristics (e.g. ventilation, space allowance and stocking density, standard of driving) and animal characteristics such as response to handling (and the quality of handling at loading and unloading), fitness to travel and response to social dynamics. Many studies have attempted to quantify the potential impact on the animal of these journeys, by measuring the inputs to the animal, such as length and complexity of the journey, temperature changes within different areas of the vehicle, physical forces applied to the animals, stocking density and air quality. Alongside these measures aspects of the animal response can also be determined including monitoring physiological changes (such as deep body temperature, heart rate, salivary cortisol, immune parameters), and behavioural responses (such as adjustments to balance, falls, vocalisations, and recovery time after transport). These can be used to model the level of environmental disturbance to the animal, and how far the animal has deviated from normal physiology, immune function and behaviour, to determine what are safe and acceptable journeys for different species to undertake.

Long journeys have been identified as being potentially more detrimental to the general welfare status of the animals, because of the longer duration of exposure to the stressors mentioned above. Therefore, it is clear that stressful journeys including hostile transport environments or conditions may influence animal health and welfare negatively. This has an impact upon productivity and profitability through changes in animal body weight, hydration state and meat quality in slaughter animals. Poor and erratic driving may impose forces in the animals which increase the risk of impacts and injuries and through postural instability will predispose animals to fatigue particularly on long journeys.

Some classes of animal, the very young, old or infirm, are particularly vulnerable to the stressors associated with transport. Newly hatched chicks, or very young calves and piglets, may be transported from the farm on which they were born to the place where they will be reared. These animals are more sensitive to thermal stress, challenges to their immune system and the physical impacts of transport and therefore their responses may be different to that of older populations. In addition, spent hens or cull cows, pigs or sheep may be suffering from an accumulation of chronic health conditions or vulnerabilities and may be less able to cope with the rigors of transport. These animals also require special consideration in transport regulation.

It is proposed by DEFRA (2018) that the “welfare of animals during transport is a broad issue that has been the subject of a large amount of past research, covering journey times, different journey types for various species, as well as the conditions during transport”. It is therefore suggested that “there is a need for a systematic review of this evidence, to assess the quality of the research, collate it and provide evidence based recommendations, including impact on current UK journeys, in order to inform policy making in this area".

Any such review should include examination of the scientific evidence relating to characterisation of current journeys; including through markets and assembly centres; and a review of the evidence on species-specific specifications on appropriate journey times which takes account of age, stocking density, feed, watering, rest intervals, ventilation requirements and space (including headroom) allowances. The review process and an associated report will Identify gaps in the research on welfare during transport and establish if there are any outstanding urgent research needs in this area. In addition the review will provide clear evidence based recommendations for future measures to achieve high welfare during transport.

Therefore **the aim of this project is to critically review the scientific evidence relating to the welfare of commercial livestock (cattle, pigs, poultry, sheep and horses) during transportation** including pre-journey preparation, handling and loading and post-journey procedures. More specifically the **objectives** of the project are to:

1. Assess the effects on welfare of long journeys i.e. intra-community trade and export journeys
2. Consider the impacts or effects of transit through markets, assembly centers and control posts
3. Identify knowledge gaps and high risk scenarios for poor animal welfare
4. Provide insight to possible improvements in practice and guides to best practice

Thus the factors to be considered in this review will include alterations to the environmental inputs that will occur in the journey as part of transport, and output measures of the response of animals to transport including behavioural and physiological measures of stress, health, pathology, injury, production outcomes and mortality.

Methodology

The systematic review will focus upon the transportation of cattle, pigs, sheep, poultry and horses. The review will cover all aspects of the transportation process including the impacts of journey times, stocking densities, thermal conditions and ventilation regimes and practices, weather and season, vehicle and container design and operation, species, age and physiological status of the animals. A key output will be the synthesis of proposals for future research requirements and/or policy strategies based on both the identified gaps in knowledge and the interactions of transport stressors with vulnerable species or classes of animal e.g. young animals (calves, piglets and newly hatched chicks) and sensitive groups such as spent laying hens or cull dairy cattle and sows.

In all cases the review will take into consideration, in addition to the actual transport phase, the pre-journey preparation of the transported animals including feeding and watering regimes, handling methods and loading as well as post-journey factors such as post-journey standing and lairage times (for slaughter animals) and unloading and holding practices. The review will also examine data and information pertaining to the movement of animals through markets, assembly centres and control posts. Thus, the review will address practices and operational variables in relation to the welfare of livestock on journeys relevant to practices in the UK and during intra-community (EU) trade and (long distance) export journeys.

Systematic Review framework

Review of the published scientific literature is regarded as an important method for the assembly, presentation, evaluation of data and findings and for balancing evidence and interpretations of findings in order to arrive at a valid consensus of opinion. In response to problems of accessing scientific information to support decision making, many applied disciplines are utilising an evidence-based framework for knowledge transfer involving systematic review and dissemination of evidence on effectiveness of interventions at the practical and policy levels (e.g. Khan et al., 2003). The framework is most fully developed in the health services sector.

It may be proposed that for the review process to facilitate the use of the presented evidence to underpin policy or specific actions in a valid manner it should follow specific guidelines and good practices (Cronin et al., 2007; Pautasso, 2013). An example of a well-structured and focussed review relating to animal transportation has been presented by Miranda de la Lama et al. (2014).

Systematic reviews differ from more traditional narrative reviews in several ways. Narrative reviews tend to be mainly descriptive, do not involve a systematic search of the literature, and thereby often focus on a subset of studies in an area chosen based on availability or author selection. Thus, narrative reviews while informative, can often include an element of selection bias. They can also be confusing at times, particularly if similar studies have diverging results and conclusions.

Systematic reviews, as the name implies, typically involve a detailed and comprehensive plan and search strategy derived *a priori*, with the goal of reducing bias by identifying, appraising, and synthesizing all relevant studies on a particular topic. Often, systematic reviews include a meta-analysis component which involves using statistical techniques to synthesise the data from several studies into a single quantitative estimate or summary effect size (Petticrew & Roberts, 2006; Uman, 2011).

Systematic reviews are an evidence synthesis approach that provides robust and transparent answers to clearly formulated questions that can directly inform risk assessments and policy development (Connor et al., 2012). Various publications have provided guidance on the optimum approaches for designing and producing systematic reviews (Piper, 2013). The purpose, design, structure and use of systematic reviews have all been extensively described and discussed (Hemingway and Brererton, 2009; Hanley and Cutts, 2013).

Systematic review and meta-analysis are established methods for answering specific questions in health care, and can be implemented to minimise bias in risk assessment (Aiassa et al., 2014). It is proposed that systematic reviews are the preferred information and knowledge source to inform policy and for decision making (Haddaway and Pullin, 2014; EFSA, 2017). Systematic review can play a key role in informing risk assessment (EFSA, 2013). It has been proposed that beyond the systematic review it is possible to employ an overview of reviews in order to achieve a more comprehensive synthesis of evidence but this approach may be susceptible to a high risk of bias (Ballard and Montgomery, 2017).

Systematic reviews have been widely applied to issues relating to animal health and welfare (e.g. Compton et al., 2017), animal sensors (Fogarty et al., 2018), animal welfare monitoring (Losada-Espinosa et al., 2018), for computing and sensor technologies for use in animal welfare (Yukan et al., 2016) and for assessing animal welfare during transport (Llonch et al., 2015).

There are 14 types of review that can be conducted to scope the literature on animal welfare and transport (Grant et al., 2009). However, to address the specified aims, the consortium has selected an extensive systematic literature review, that in contrast to traditional or narrative literature reviews and as described above, is designed to provide a more rigorous and well-defined approach to reviewing the literature in a well defined and specified area. Therefore the systematic literature review has examined material published in the last ~50 years relating to animal transport and welfare consistent with the aims specified above.

In addition to the examination, classification and evaluation of all the available scientific literature in the pertinent areas the review process has been complemented by a systematic search appraisal and evidence extraction and assimilation from the scientific and “grey” literature, trade publications and recently published documents relating to transport practises and animal welfare from European (e.g. EFSA and DG SANTE) and UK agencies (e.g. Defra) as well as NGOs and trade publications.

Quality assessment of material for inclusion and exclusion of the review has been conducted based on parameters specified by the project aims and has been refined during initial meetings with Defra. This extensive assessment has allowed the project consortium to make recommendations based on what is currently known, gaps in the scientific literature, limitations in current EU/UK legislation, uncertainty around scientific findings and recommendations for future research.

Systematic and Narrative Review approaches

As discussed in detail elsewhere there are many advantages associated with the use and application of Systematic Reviewing (SR). However in relation to the current report on the Welfare of Livestock during Transport the systematic approach may exclude or omit useful information. This stems from the fact that the selection/exclusion criteria for SR may eliminate some publications and information sources from the final analysis. Thus, a systematic review may ensure that the quality of the publications included in the final analysis may be very high and this is key if a meta-analysis is to be performed also but some important work may not qualify for final inclusion. Thus, the synthesis of overviews as they appear in narrative reviews will be excluded as not being a primary research peer-reviewed publication or commissioned work may appear in project reports submitted to the original funder but this work may not have subsequently appeared in refereed publications. Therefore, in the present report the systematic review which has yielded useful statistics on the number, topic, origin and quality of research papers has been supplemented with identification and inclusion of other sources of information in relation to gaps in knowledge and possible future requirements. Thus, the systematic review has identified important gaps in knowledge where there are few or no publications of high standard that might better inform current and future policy but attempts have been made to identify other sources of data or findings that might inform these areas.

Systematic Review methodology

The search criteria and strategy have been defined around the literature and material published from 1st January 1968 to 31st March 2018. All experimental and observational scientific studies of animal transport (including research papers, conference proceedings and literature reviews) as well as non-scientific publications (e.g. Agencies, Authorities and NGOs) relating to welfare and conditions of animal transport, animal handling before, during and after transport, animals in markets, assembly centres, control posts have been included.

Searches will be performed using the same search terms in a minimum of four key search engines (1) PubMed; (2) Science Direct; (3) Scopus; and (4) Web of Knowledge.

The search terms used (including all titles, abstracts and keywords) have included:: TITLE: (transport* OR market* OR transit* OR lairage* OR control post* OR assembly* OR handling* OR vehicle*) AND TOPIC: (animal welfare* OR physiology* OR behaviour* OR indicator* OR quality* OR stress* OR operation OR design*) AND TITLE: (animal* OR livestock* OR farm animal* OR cattle* OR bovine* OR calf* OR cow* OR beef* OR dairy* OR heifer* OR sheep* OR lamb* OR poultry* OR chick* OR turkey* OR broiler* OR layer* OR duck* OR bird* OR pullet* OR hen* OR pig* OR hog* OR swine* OR sow* OR piglet* OR dog* OR canine* OR horse* OR equine* OR equid* OR camelid* OR llama* OR alpaca* OR goat* OR kid* OR caprine*) NOT TOPIC: (transporter) NOT TOPIC: (cell). Only documents written in English have been included unless translations were readily accessible and any duplication has been omitted. Timespan=1968-2018.

The systematic review is a methodological framework to identify evidence in a non-biased and independent review of the literature. In order to achieve this, the process undergoes a three phase approach to identify scientific publications pertinent to the defined aim through eligibility criteria (Phase 1), assessment and quality (Phase 2) and finally ranking the publications in relation to the quality and relevance (phase 3). The defined aim of the systematic review was agreed with funders as:

“To identify and evaluate “key” published research materials and outputs representing the sound scientific basis (evidence) for improved practices, policy and legislation for animal transport”. The systematic search and selection of evidence and material was performed with all domain experts being blinded to the paper authors and journal during phase 1 and 2. Phase 1 involves the development of the search times and piloting multiple permutations of this while providing spot checks in order to establish that key papers are not being missed. The final search terms were identified following extensive piloting and 12 permutations. Once the search terms were finalised, the final search was run. The papers exported from the search then entered the three phase process. Phase 2 involved a more detailed assessment from each paper and were often double assessed by two domain experts and checked for assessor reliability. Data was extracted (Table 1) for all papers which entered the phase 2 assessment, and the papers were grouped and identified into further refined criteria topics in order to identify records with welfare criteria and by parameters (e.g. species, mode of transport).

Phase	Criteria	Details
Phase 1 (Eligibility criteria)	English language only Time span	no translation requirement 1968-2018
	Published	
	Peer-reviewed	
	no author communication	
	Species specified	e.g. sheep, cattle, poultry, pigs, horses
	Topic specific	Animal transport and related practises (e.g. handling at transport, no general animal handling)
	Experimental papers only	Reviews of the literature were identified and excluded from Systematic review, but not removed from the reference database, as they would be informative to the narrative.
	Conference proceedings excluded	
	Open access availability (including "green access"	
Phase 2 (assessment and quality)	Allocation to welfare criteria topics	• Stocking Density / Space allowance (plus head space / clearance) • Journey Duration (travel time through markets) • Loading (handling) • Unloading (including. control posts and markets) • Fitness to Travel • Ventilation • Thermal environments • Feeding • Watering • Accelerations and impacts, standard of driving • Social/group dynamics (mixing)
	Obsolete practises	Papers which reported on obsolete practices, procedures or operations were removed. This included practices and operations that are prohibited, constrained or limited by current legislation. Exceptions were those papers in which comparative studies of practices and operations provided insight in to the appropriateness of current legislation or guidelines.
	Exclude papers with 0 citations if published for >5yrs	
	Exclude papers which have no welfare implications addressed	
	Sample size	Data extraction
	replication	Data extraction
	Species identified	Data extraction e.g. cattle
	Sub-categories of papers identified	Data extraction e.g. cattle > calves or dairy or beef etc.
	Type of transport	Data extraction e.g. road, sea, air
	Continent to which the work was conducted in	Data extraction

	Experimental outcome measures specified	Data extraction: • Behavioural • Physiological • Meat quality • Disease/pathology • Mortality (inc. DOAs) • Stress/welfare
	Journey times identified	Data extraction
	Journey distances identified	Data extraction
	Thermal environment identified	Data extraction
	Stocking density/space allowance	Data extraction
Phase 3	Score 1 (lowest quality ranking)	According to data extracted the publication was identified as either one or a combination of the following: • No replication • No welfare outcomes • Small sample size • Mode of transport details insufficient • <1 citation yearly average from publication date
	Score 2 (Medium quality ranking)	According to data extracted the publication was identified as either one or a combination of the following: • Sufficient replication and sample size • Welfare outcomes identified • Mode of transport detail sufficient •
	Score 3	According to data extracted the publication was identified as either one or a combination of the following: • Provided guidance and conclusions relating to Welfare policy • Provided basic information that might be interpreted as being policy relevant • Providing fundamental new knowledge that informs transport practices, legislation or policy • Identified new or little understood issues of welfare concern in animal transport • Provided information or data supporting current practices and legislation • Provided new fundamental data and information that increase understanding of transport welfare issues • Would meet all the criteria employed in Framework of Excellence assessments for a 3 or 4 star publication

Table 15 Summary of the Systematic Review process and selection criteria

A review of the evidence on welfare aspects of the transport of live animals (AW0821)

Introduction

The EU first developed and adopted overarching rules governing animal welfare during transport in 1977 (EC, 1977). It was stated that all such rules should aim to eliminate technical barriers to trade in live animals and to allow market organisations to operate smoothly, while ensuring a satisfactory level of protection for the animals concerned.

The EU legislation relating to animal transportation was last updated by Council Regulation (EC) No 1/2005 (EC, 2005) on the protection of animals during transport and related operations and amending Directives 64/432/EEC and Regulation (EC) No 1255/97 which was adopted on 22nd December 2004. The "Transport Regulation" was implemented throughout the European Union in January 2007. Parallel domestic legislation was introduced within England, Wales, Scotland and Northern Ireland to implement the Regulation. Subsequently the content of the Regulation has been the subject of a further Scientific Opinion (EFSA, 2011) and according to that EFSA opinion "parts of the Regulation are not fully in line with the current scientific knowledge". The impact and efficacy of the Regulation have been considered also in a study commissioned by SANCO (SANCO, 2012). This latter study proposed that the Regulation resulted in positive improvements in animal welfare in transit and made 3 key recommendations:

1. Harmonise the implementation, enforcement and the penalties within EU Member States and improve the communication between Member States.
2. Do not change the existing Regulation because it will slow down the present developments. Only if the present Regulation leads to poor or unacceptable animal welfare should exceptions be made (i.e. travelling times as recommended by EFSA (2011 – see above).
3. Support the development of good guides to practices especially if these are developed by chain participants.

As mentioned above, the Regulation has had beneficial impact on the welfare of animals during transport. However, it appears that there is room for improvement of the situation. Those improvements could be achieved by different actions and it should be emphasised that for the vast majority of animals falling under the scope of the Regulation, the Commission does not see that an amendment would be the most appropriate approach to address the identified problems. A stable legal situation will allow Member States and stakeholders to focus on enforcement within a stable legal framework. As regards the gap between the requirements of the legislation and available scientific evidence, the Commission sees that, for the time being, this is best addressed by the adoption of guides to good practices.

The current report is based upon a systematic review of scientific literature pertaining to the welfare of animals during transportation. The precise methodology is described in detail elsewhere in the review document. The outputs from the current systematic review and the associated recommendations may inform future application, modification and enforcement of animal welfare legislation (post-Brexit) and relevant guidance. Therefore it is proposed that the review process should be structured in accordance with of the Annex I (Technical Rules) to Regulation (EC) No 1/2005 legislation and the associated EFSA Scientific Opinions in relation to identified risks to animal welfare in transit for each species.

Species covered in the review:

(1) Calves, cattle
(2) Pigs
(3) Sheep
(4) Poultry
(5) Horses
(6) Others (Goats)

Identified welfare risks during transportation are:

(1) Fitness for Transport

(2) Means of Transport

(3) Loading and Unloading / Handling

(4) Space Allowances

(5) Transport Practices

(6) Feeding and Watering

(7) Thermal conditions and Ventilation

(8) Journey times and rest periods

(9) Long journeys

(10) Sea and air transport

(11) Other specific issues

Systematic review summaries

The systematic review returned **4350** publications according to the search terms specified, over the last 50 years.

Phase 1 filtering (refer to methods for criteria) reduced this total number to **699** publications.

Phase 2 and 3 filtering (refer to methods for criteria) reduced this total number to **328** publications, including a total of **33** publications were reviews or non-experimental studies.

Following the systematic review methodology a total of 328 published papers were identified over the last 50 years which met the criteria in terms of relevance, quality and impact. Of those 328 papers the following were grouped by species: pigs 89, poultry 81, cattle 50, sheep 38, horses (equine) 35, mixed/multiple species 16, goats 15, dog 1, other 3 and 2 being non-species specific and related to transport design and engineering studies. The spread of publications by year and subdivided by species is shown in Figure 1 and Figure 2. The publication period selected was from1968 to March 2018. Clearly the key period for new or novel work addressing the key components of current animal transportation legislation, guidelines and practices is from 2005 until the present. This assertion is based on the fact that EFSA undertook extensive reviews in 2002-2004 upon which the legislation EC 1/2005 was developed. Many important and more recent publications were then identified and presented in the EFSA review in 2011. No publication prior to 1981 passed all criteria for the three phase assessment process for the review, and no publication prior to 1977 made it through phase 2. Figure 2 demonstrates the large variation of publications across species. The largest number of publications overall were seen in pigs (89), followed by poultry (81). The publication of the three European Food Safety Authority reviews (2002, 2003, and 2004), are followed by an increase in publications, in number as well as quality and relevance to the nine criteria of interest (e.g. means of transport). However, when the publications are identified by species (Figure 2), it is clear that the increases in publication rate are primarily focussed on pigs, poultry and cattle. There is a lesser upward trend in publication rate in horses, goats (included in "other") and sheep, although the absolute numbers are lower. This would suggest that the reviews and their identified gaps in knowledge may have stimulated some further research in the post EC 1/2005 era. Figure 3 provides detail by sub-grouping of the species classification by age and production type. The important fact to note is that no papers published met the standards for inclusion in the systematic review for the following sub-groups: breeding bulls, boars, rams, foals and donkeys/mules.

Table 16 Total number of publications in the final phase of the systematic review, grouped by species and internal sub-groups. Knowledge gaps in animal welfare research into different modes of transport for each species sub-group are identified by greyed cells.

Species	Sub-group	Total number of publications
Cattle	beef cattle/steers	38
	Calves	10
	breeding bulls	0
	dairy cattle/heifers	5
Poultry	Broiler	54
	Chicks	13
	Duck	3
	Duckling	1
	layer hen	3
	layer pullets	1
	Turkey	5
	turkey poults	1
Pigs	Piglet	5
	slaughter pigs	72
	Sow	3
	Weaner	9
	Boars	0
Sheep	Lamb	15
	adult sheep	22
	Rams	0
Equine	slaughter horse	3
	racing/companion horse	32
	donkeys/mules	0
	Foals	0
Other	Dogs	1
	Goat	15
	other (e.g. reindeer, alpaca)	14

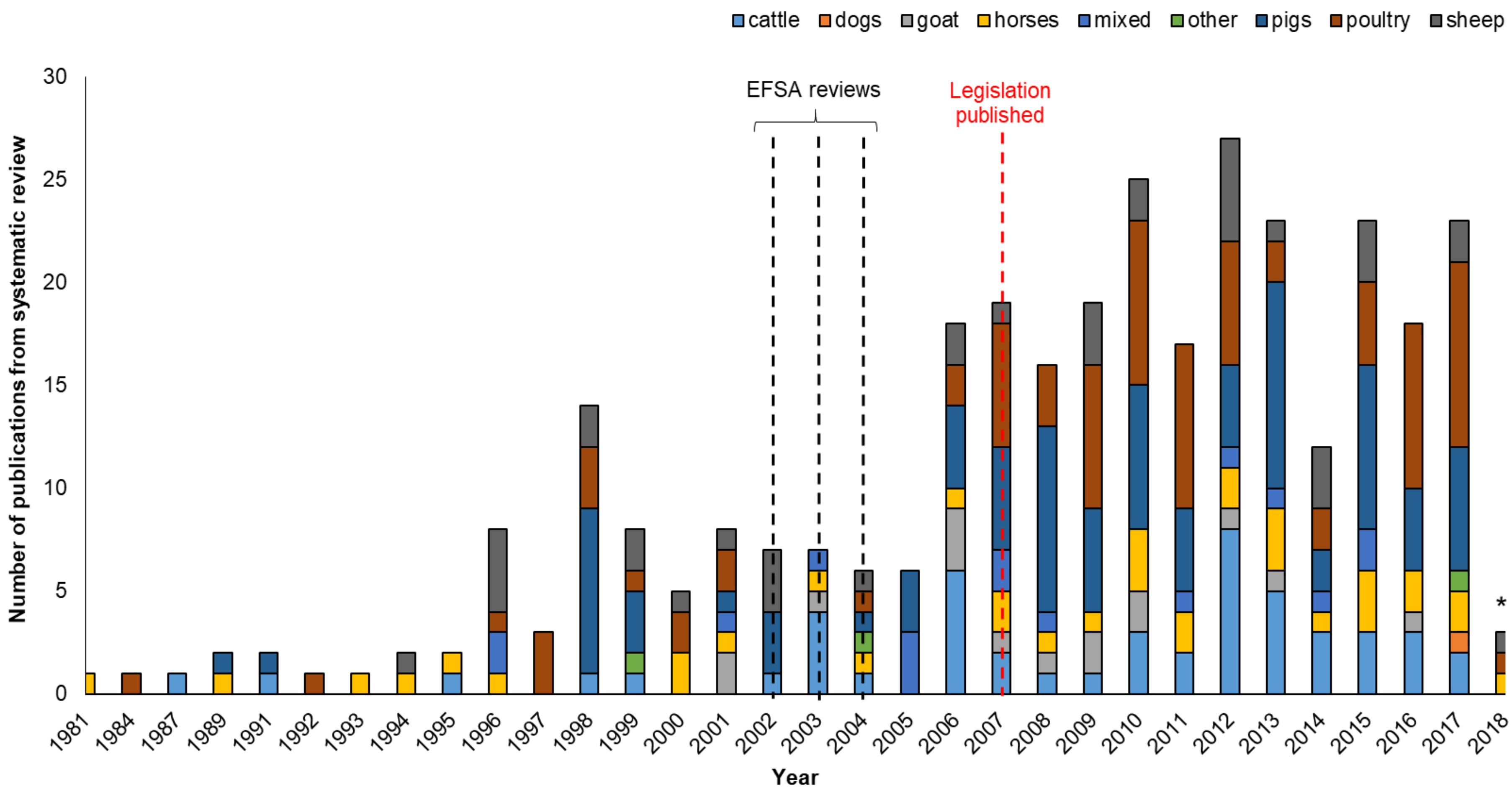


Figure 3 Number of papers published identified and screened and meeting the criteria for inclusion in the systematic review process (total period 50 years but no papers pre-1981 qualified for inclusion). The publication of the three European Food Safety Authority (EFSA) literature reviews on animal transport have been labelled, as well as the publication of the European Council Regulation EC 1/2005 on Animal welfare during transport. The asterisk identifies publication years which are no yet ended.

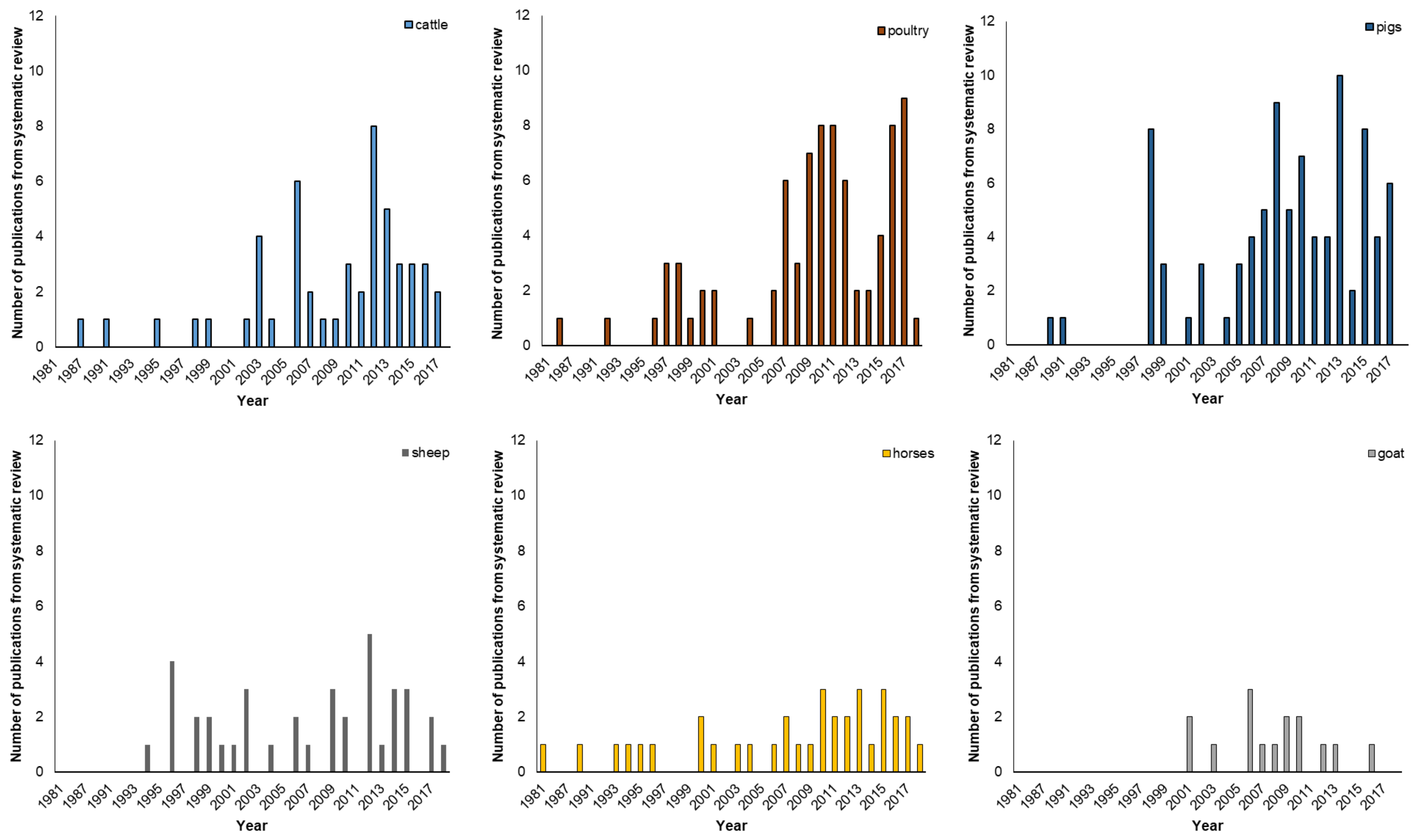
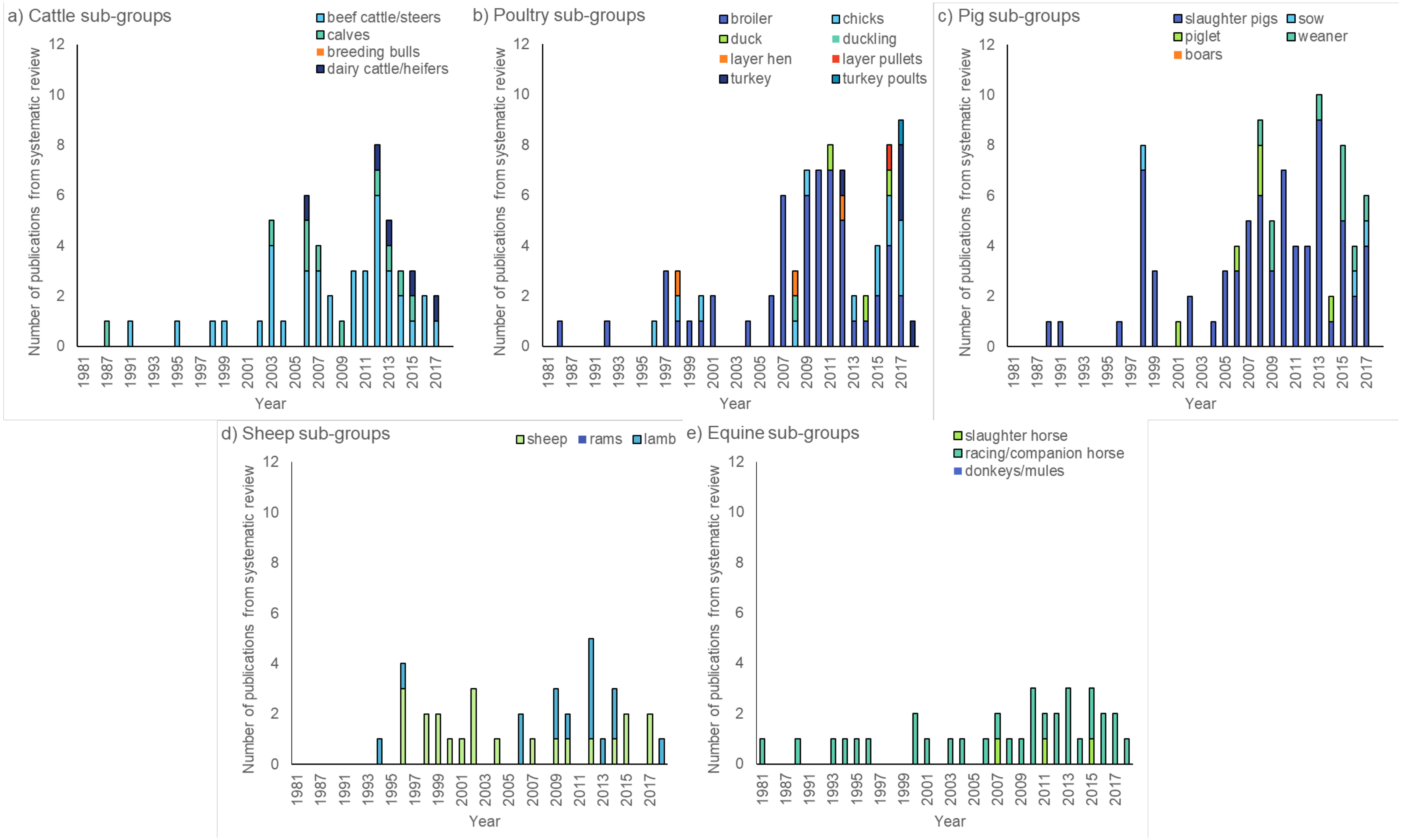

cattle
poultry
pigs
sheep
horses
goat
Number of publications from systematic review
Year

Figure 4 **Quantity of papers published that were identified and screened in the systematic review, grouped by species.**



a) Cattle sub-groups
beef cattle/steers
calves
breeding bulls
dairy cattle/heifers
b) Poultry sub-groups
broiler
chicks
duck
duckling
layer hen
layer pullets
turkey
turkey poults
c) Pig sub-groups
slaughter pigs
sow
piglet
weaner
boars
d) Sheep sub-groups
sheep
rams
lamb
e) Equine sub-groups
slaughter horse
racing/companion horse
donkeys/mules
Number of publications from systematic review
Year

Figure 5 Histograms of papers published identified and screened for inclusion in the systematic review, grouped by species and further sub-grouped by age and production role.

The majority of publications relating to animal transport and welfare are focussed on road transport (Table 3, Figure 4), with a total of 310 publications on this mode of transport over the selected review period. The least studied mode of transport was air transport (total = 6), however sea (i.e. ferries) was only marginally higher. Interestingly, only cattle and poultry have publications in non-specified modes of transport, however, these papers relate to either reviews or design of ramps, crates etc. When comparing the number of publications by year and mode of transport (Figure 4), EFSA reviews of the early 2000s do not appear to have impacted on the number of publications into different modes of transport, with the majority still focussed on road transport, although there is a marginal trend for an increase in publications for sea travel after 2005. Table 4 demonstrates the extreme knowledge gaps in both air and sea transport of animals, with the majority of species receiving little or no attention.

The average score of publications attributed in the systematic review process was highest in road transport (1.6±0.1), followed by sea (1.5±0.1), and lastly air transport (1.3±0.2).

Table 17 Summarising the number of publications from the systematic review in relation to mode of transport and subdivided by species group. Knowledge gaps in animal welfare research into different modes of transport for each species sub-group are identified by greyed cells.

Type of transport	cattle	dogs	goat	horses	mixed	other	pigs	poultry	sheep
air				5				1	
road	46	1	15	30	13	3	89	78	35
sea	2				3				3
Non-specified (e.g. handling)	2							2	
Grand Total	50	1	15	35	16	3	89	81	38

Table 18 Summarising the number of publications from the systematic review in relation to mode of transport and subdivided by species subgroups. Knowledge gaps (zero publications) in animal welfare research into different modes of transport for each species sub-group are identified by greyed cells and criteria with limited research (<5 publications) are identified by blue cells.

Species	Sub-group	air	road	sea
Cattle	beef cattle/steers		34	2
	Calves		10	
	breeding bulls			
	dairy cattle/heifers		5	
Poultry	Broiler		54	
	Chicks	1	11	
	Duck		3	
	duckling		1	
	layer hen		2	
	layer pullets		1	
	Turkey		5	
	turkey poults		1	
Pigs	Piglet		5	
	slaughter pigs		72	
	Sow		3	
	weaner		9	
	Boars			
Sheep	Lamb		14	1
	adult sheep		20	2
	Rams			
Equine	slaughter horse		3	
	racing/companion horse	5	27	
	donkeys/mules			
	Foals			
Other	Dogs		1	
	Goat		15	
	other (e.g. reindeer, alpaca)		11	3

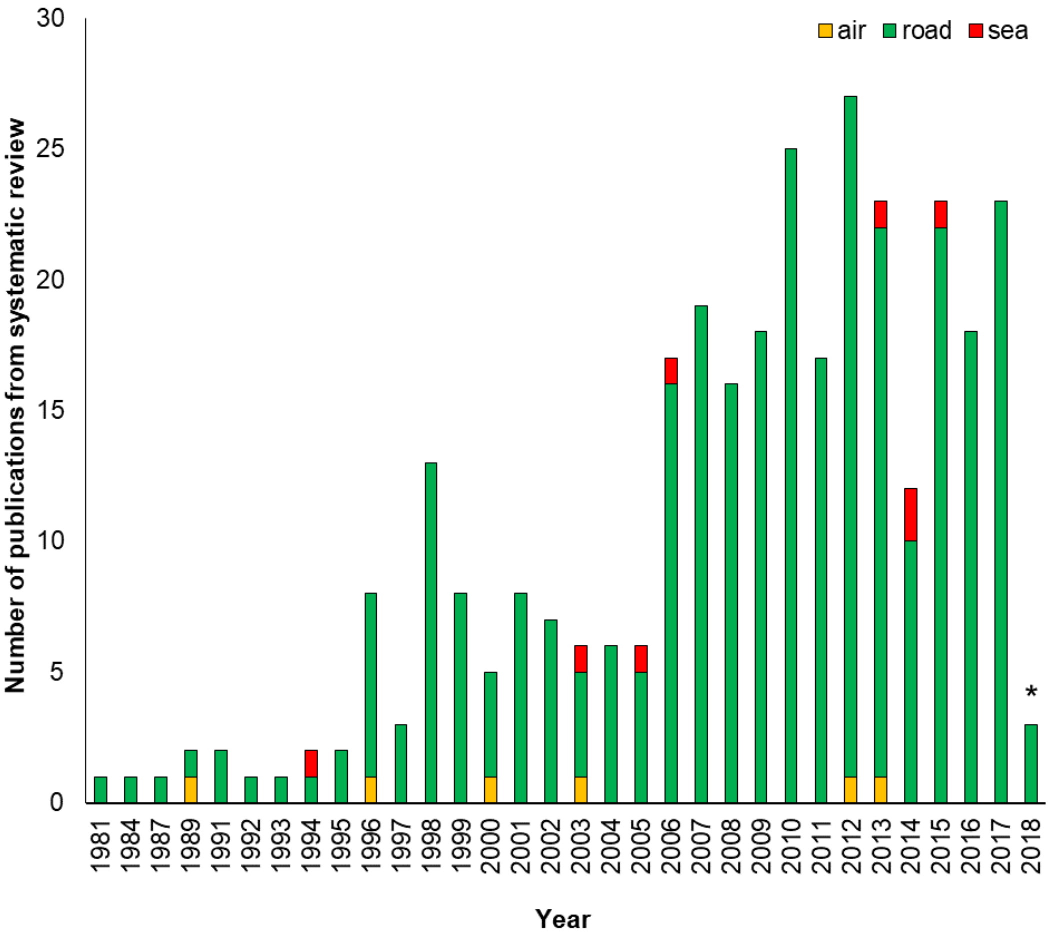


Figure 6 Histogram of publications by year since 1981, and grouped via mode of transport investigated (air, sea and road).

The regional origins of publications pertaining to the welfare of livestock during transportation are presented in Figures 5 & 6. Europe is the major contributor of publications relating to animal welfare outcomes and animal transport. However, following the publication of the three EFSA reviews in the mid-2000s, the Americas, Asia and Africa increased their contribution. The highest contributor for cattle was Europe (19), closely followed by North America (17), with Africa contributing the least (1). For Poultry, again Europe was the largest contributor (35), double that the second highest contributor (North America, 16). Australia contributed the least to poultry (1) and pigs (2). The main contributor for pigs was North America (37), closely followed by Europe (35). For both equine and sheep, Europe was the main contributor (14, 27 respectively). Africa contributed no publications to equine research and Africa (1), Asia (1) and North America(1) jointly contributed the least to sheep. In stark comparison to other species, Australia and the Americas did not contribute to research into goat transport and Europe only contributed one publication.

Similarly the average total number of citations per publication is highest in Europe (22.3±2.1) and lowest in South America (9.4±1.9). Africa, Asia, Australia and North America were all relatively similar, ranging from (12.0-15.5). The average score of publications by continent was highest in Europe (1.7±0.1) and lowest in Asia (1.4±0.1), with remaining continents ranging from 1.5-1.6.

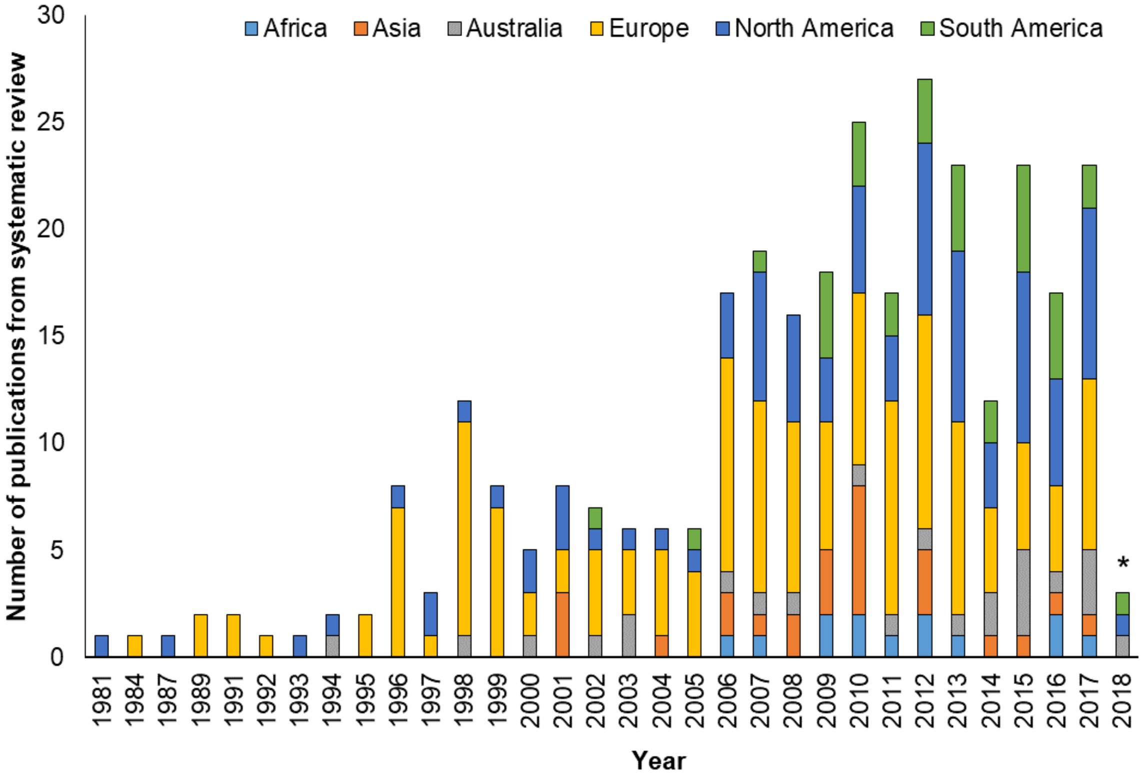


Figure 7 **Histogram of publications by year since 1981, and grouped via continent in relation to where the experimental study was conducted, not the author affiliation.**

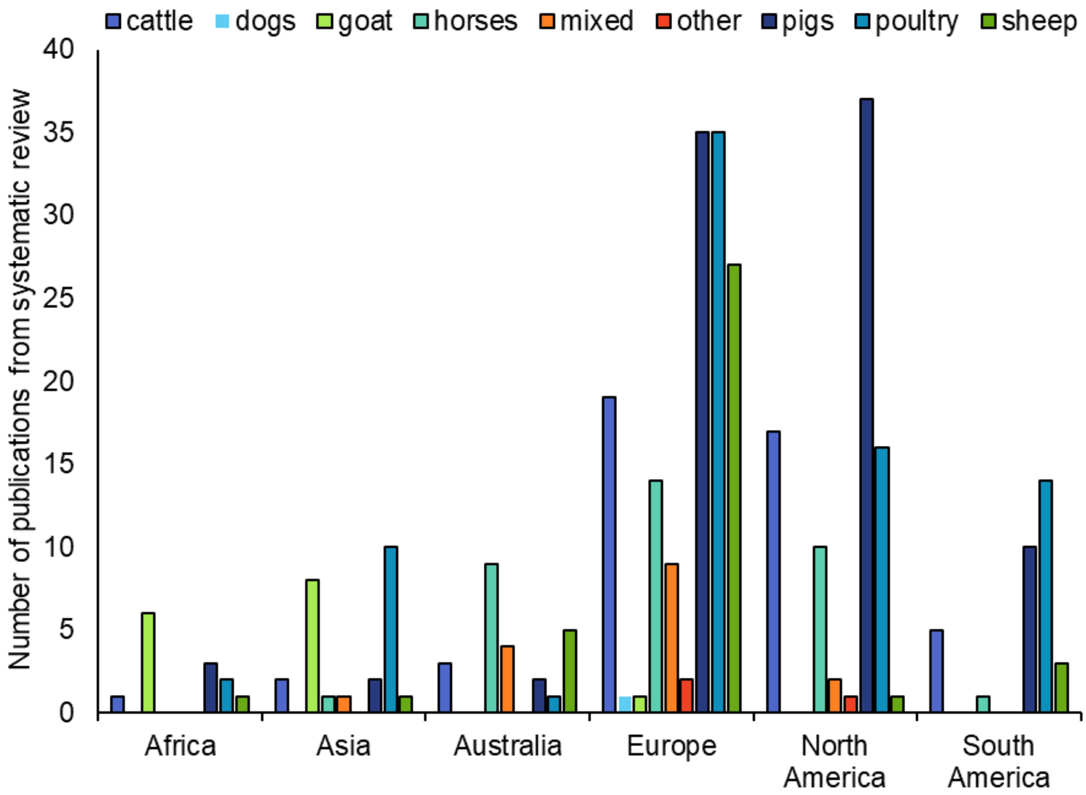


Figure 8 Histogram of publications by continent (in relation to where the experimental study was conducted), and grouped via specie

When grouped generally by species (e.g. cattle, sheep) the knowledge gaps (zero publications) appear limited to welfare research at markets and long journeys compliant with current EU legislation (Table 5). However, when considering the areas of limited welfare research, the knowledge gaps widen, with reduced information provided on lairages, markets, fitness to travel, feeding and watering and long journeys compliant with current EU legislation (Table 5).

Table 6 shows the knowledge gaps and limited research areas even more noticeably when the species are broken down into their internal sub-groups. The only species sub-groups which appear to have extensive welfare research across all welfare criteria are beef cattle/steers, broilers and slaughter pigs. While breeding bulls, dairy cattle, ducks, ducklings, layer hens, layer pullets, turkeys, turkey poults, piglets, sows, weaners, boars, rams, donkeys/mules, foals and dogs all show only limited research in all welfare criteria.

Figure 7 depicts the spread of welfare variables used to measure welfare in these publications. “Stress outcomes” are most commonly used across all species, followed closely by either behavioural or physiological outcomes.

Table 19 Counts of papers from the systematic review grouped by welfare criteria and by species. Knowledge gaps (zero publications) in animal welfare research into different modes of transport for each species sub-group are identified by greyed cells and criteria with limited research (<5 publications) are identified by blue cells.

Species	Lairage	Market	Fitness to travel	Means of transport	Loading, unloading (handling)	Space allowances	Transport practices	Feeding and watering	Thermal conditions	Journey times and rest periods	Long journeys (>8hrs)	long journey compliant
cattle	5	1	3	8	7	5	30	13	12	31	19	10
horses	2		7	12	12	9	21	4	8	26	13	4
mixed	2	1	3	9	8	5	12	4	8	7	1	
other	2		3	2	3	5	7	2	9	15	2	
pigs	17		10	26	24	30	25	8	37	51	25	8
poultry	21		12	22	12	14	40	8	40	44	18	16
sheep	7	3	2	10	11	13	25	3	14	31	8	2

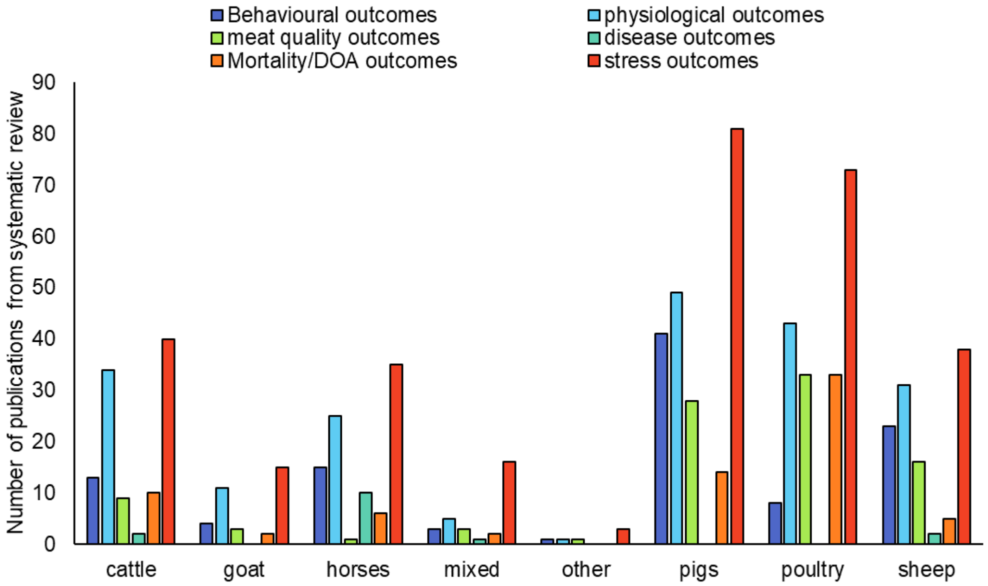


Figure 9 **Histogram of publications by welfare variable outcome grouped by species.**

Table 20 Counts of papers from the systematic review grouped by welfare criteria and by species and their sub-groups. Knowledge gaps (zero publications) in animal welfare research into different modes of transport for each species sub-group are identified by greyed cells and criteria with limited research (<5 publications) are identified by blue cells.

Species	Sub-group	Lairage	Market	Fitness to travel	Means of transport	Loading, unloading (handling)	Space allowances	Transport practices	Feeding and watering	Thermal conditions	Journey times and rest periods	Long journeys (>8hrs)	Long journey compliant
Cattle	beef cattle/steers	5	1	1	8	6	5	24	10	10	22	15	7
	calves	1		1		2		7	4	1	7	3	2
	breeding bulls												
	dairy cattle/heifers			1	1		1	3		3	2	1	1
Poultry	broiler	17		8	18	10	10	30	7	32	31	7	6
	chicks			2	2	1		5	2	3	6	7	6
	duck	2						1		1	3	1	1
	duckling							1			1	1	1
	layer hen	1		1	1	1	1			1	1		
	layer pullets							1		1	1		
	turkey	1		1	2		4	2		3	1	2	2
	turkey poults			1				1					
Pigs	piglet			1	1	1	2	1	1	4	5	3	
	slaughter pigs	1		6	22	21	22	18	6	27	38	20	8
	sow			1	2	2	2	2		2	3		
	weaner	1		2	2	1	4	4	1	4	4	2	
	boars												
Sheep	lamb	4			3	2	5	7	1	4	13	4	1
	adult sheep	1	2	1	7	8	7	17	2	9	17	4	1
	rams												
Equine	slaughter horse	1			1		1	1	1		3	3	3
	racing/companion horse	1		7	11	12	8	20	3	8	23	10	1
	donkeys/mules												
	Foals												
Other	Dogs	1		1		1	1	1			1		
	goat	1		1	2	2	3	4	2	9	14	2	
	other (e.g. reindeer, alpaca)			2	5	7	3	6	1	4	10	1	

The most cited paper (total of 129 citations) from those systematically reviewed was Mitchell & Kettlewell, 1998 “Physiological stress and welfare of broiler chickens in transit: Solutions not problems!”, however this was a literature review. Once reviews were excluded, the most cited publication was Warris et al (2003) “Effects on cattle of transport by road for up to 15 hours”.

- “Lairage” has an average total citations per publication of 20.2±0.4 and the average number of citations per year of 1.6±0.1

- “Market” has an average total citations per publication of 17.0±2.2 and the average number of citations per year of 2.0±0.3

- “Fitness to travel” has an average total citations per publication of 17.8±0.5 and the average number of citations per year of 1.9±0.1

- “Means of transport” has an average total citations per publication of 9.6±0.2 and the average number of citations per year of 1.4±0.1

- “Loading, unloading (handling)” has an average total citations per publication of 12.9±0.3 and the average number of citations per year of 1.5±0.1

- “Space allowance” has an average total citations per publication of 12.9±0.3 and the average number of citations per year of 1.5±0.1

- “Transport practises” has an average total citations per publication of 16.2±0.3 and the average number of citations per year of 1.4±0.1

- “Feeding and watering” has an average total citations per publication of 22.5±0.6 and the average number of citations per year of 1.9±0.1

- “Thermal conditions” has an average total citations per publication of 14.1±0.2 and the average number of citations per year of 1.3±0.1

- “Journey times and rest periods” criteria has an average total citations per publication of 18.1±0.2 and the average number of citations per year of 1.6±0.1

- “Long journeys (>8hrs)” has an average total citations per publication of 17.5±0.3 and the average number of citations per year of 1.6±0.1

- “Long journeys (>8hrs), EU compliant” has an average total citations per publication of 13.8±0.6 and the average number of citations per year of 1.3±0.1

By species, the average total number of citations was highest for cattle (20.9±3.4) and the lowest for other (9.3±4.7). Interestingly, despite the low numbers of publications in air (13.0±2.5) and sea (9.2±3.5) transport, the average total number of citations per publication are reasonably close between the different modes of transport, including road transport (17.7±1.3). Figure 8 and Table 7 shows the scores of publications (as defined in Table 1) over the time-span of the systematic review.

Table 21 Publication scores (mean, SE, minimum and maximum) categorised by species.

Species	Mean	SE Mean	Minimum	Maximum
cattle	1.6	0.07	1	3
horses	1.6	0.09	1	3
mixed	1.7	0.14	1	3
other	1.3	0.33	1	2
pigs	1.6	0.05	1	2
poultry	1.5	0.05	1	3
sheep	1.5	0.08	1	2

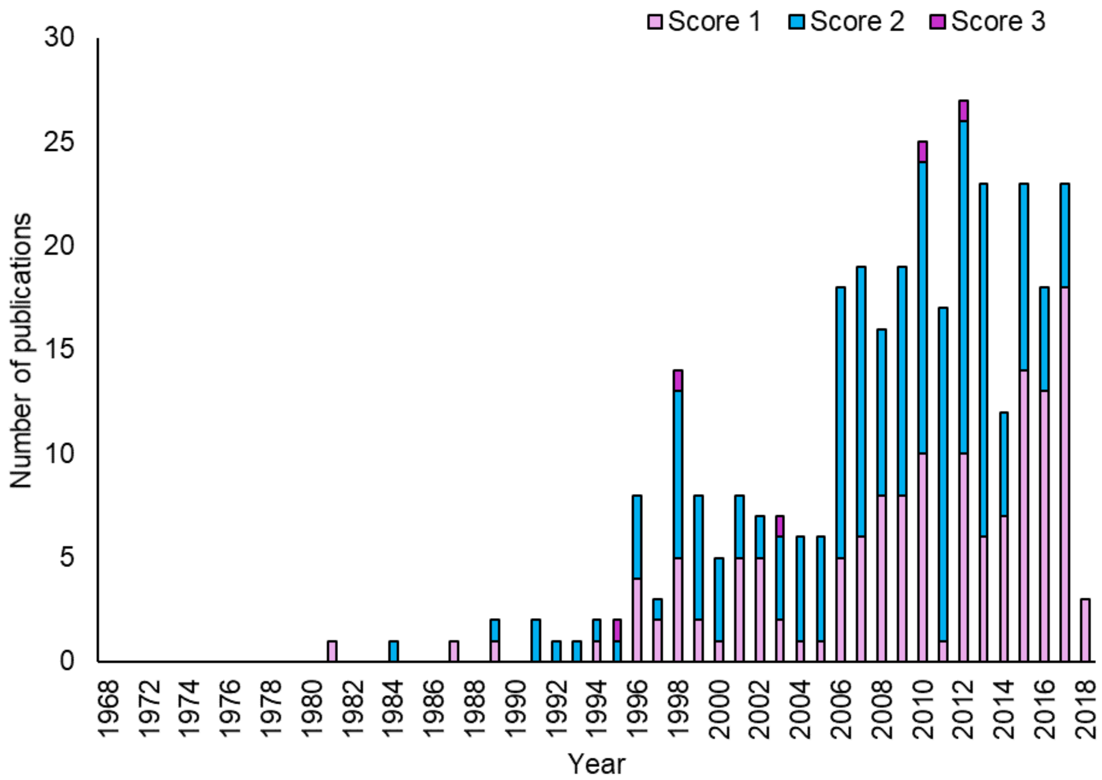


Figure 10 Scores of publications over the time-span of the systematic review

CATTLE

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). 'Good practices for animal transport in the EU: cattle (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have identified the main areas of welfare concern for the transport of cattle and calves. These have been addressed through identification and integration of recommendations for good and best practice from scientific knowledge, scientific literature, experiences and information from stakeholders.

Transport of animals involves several potential stressors that can affect welfare negatively. The new and unfamiliar environment, movement restrictions due to confinement, vibrations, sudden and unusual noises, animal fitness, mixing with other animals, temperature and humidity variations together with inadequate ventilation and often feed and water restrictions all have an impact on the animals' state. The effects of all these factors on livestock are influenced by the experience and condition of the animals, the nature of the journey, and the duration of transport.

Inadequate consideration of altering space allowance / head room in response to a range of factors may also pose risks. Weather and thermal conditions should be considered and space should be adjusted to minimise the risk of thermal stress. In addition transportation of horned and pregnant animals also requires additional space above the minimum standards required by transport legislation (EC 1/2005).

Transportation of young calves (particularly on long journeys) imposes specific challenges, in particular feeding and watering in compliance with the legislation is often very difficult to achieve as calves will not use the equipment provided. Calves can only be successfully fed and watered (or provided with milk/substitute/electrolytes) after unloading and this should take place at a control post, market or assembly centre. This problem will impact upon maximum journey times permitted (19 hours) under the EC Regulation as young calves have to be provided with feed/water after as little as 8-9 hours.

Another important practical consideration and a significant risk to welfare is the scheduling of milking of lactating cattle when transported. It is essential to ensure that facilities and personnel are available at the relevant times and locations during a properly planned journey (e.g. immediately upon arrival at the final destination or intermediate port) to avoid delays in milking.

Significant stress may be associated with loading or handling prior to loading, also considering that animals may have undergone periods of water or feed deprivation prior to loading and transport. Journey times are frequently extended due to traffic congestion and this may compound welfare impacts during times of extreme temperatures. International and intra-community trade involving prolonged journeys, especially those requiring movement over water, may result in specific additional welfare challenges in conditions of transport (e.g. if by boat or, less commonly, air) and disease risk. Familiarity of cattle within a group, sympathetic handling at loading and unloading, shorter journey times, consideration of space allowance and careful driving appear to reduce the risk of poor welfare and injury during transportation. Transporting horned animals increases the risk of injury to other stock being transported.

The transportation of cattle will now be considered under the headings identified above and derived from the structure of EC 1/2005 and associated annexes. Schwartzkopf-Genswein et al (2012) have reviewed road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: The main effects of loading density, trailer microclimate, transport duration, animal size and condition, management factors including bedding, ventilation, handling, facilities, and vehicle design were summarized by species. The main risk factors listed above all have impacts on welfare (stress, health, injury, fatigue, dehydration, core body temperature, mortality and morbidity) and carcass and meat quality (shrink, bruising, pH, colour defects and water losses) to varying degrees. It was concluded that road transport of livestock is a multi-factorial problem where a combination of stressors rather than a single factor is responsible for the animal's well-being and meat quality post transport. Animals least fit for transport suffer the greatest losses in terms of welfare and meat quality while market ready animals (in particular cattle and pigs) in good condition appear to have fewer issues. More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions. Future research needs to focus on controlled scientific assessments, under North American conditions, of varying loading densities, trailer design, microclimate, and handling quality during the transport process. Achieving optimal animal well-being, carcass and meat quality will entirely depend on the quality of the animal transport process.

Fitness for Transport

The knowledge and experience of animal transport drivers relating to fitness to travel in dairy cows has been examined by Herskin et al. (2017). Using a questionnaire-survey 66 drivers were asked to provide information concerning their knowledge of the assessment of fitness to travel. 94% of respondents stated that they knew the rules regarding fitness for transport. More than half of the respondents said that physical conditions (light, space) before loading animals allowed proper assessment of fitness for transport, and 85% answered that time constraints were not a challenge for this. Thirty-five percent reported to be in doubt regarding fitness for transport of specific cows at least frequently, and given two specific questions on legislation concerning fitness for transport, only 52% of the respondents answered both correctly. As drivers are held partly responsible for fitness for transport of animals sent to slaughter, and descriptions of fit / unfit are rather vague, livestock drivers may require additional education, training, assessment tools or feedback in order to optimize the welfare of animals to be transported.

> Animals least fit for transport suffer the greatest losses in terms of welfare and meat quality compared to market-ready animals in good condition. A new assessment system for fitness to travel in cattle should be developed and applied. There is evidence also that livestock drivers may require additional education, training, assessment tools or feedback in order to optimize the welfare of animals to be transported.

Handling, Loading and Unloading

Fukasawa et al. (2012) have examined the effects of calf training, by loading at weaning, on behaviour at later loading. Trained calves were loaded significantly faster than control calves. Trained calves baulked less during loading than control calves. Heart rates of handlers after loading were significantly lower in the trained group than in the control group; however, salivary amylase activity and cortisol concentration was not different between groups. Physical effort and stress on handlers was similar in both groups. Heart rate, plasma cortisol, NEFA and CPK of calves were significantly increased only in the control group after loading. It was stated that calf training improves loading efficiency and reduces stress on calves.

Hagenmaier et al. (2017) have analysed the effects of handling intensity at the time of transport to slaughter on the physiological responses and carcass characteristics of feedlot cattle fed ractopamine hydrochloride as a growth and meat quality promotor. It was suggested that low-stress handling at the time of transport for slaughter is essential. The value of the study is limited as the animals were treated with ractopamine.

Cattle should be familiarised with handling and loading procedures prior to journeys particularly long journeys. Pre-conditioning was beneficial for calves pre-transport in that they were better able to tolerate the stressors of transport and handling. In addition, the combined effect of conditioning and short-haul transport was least stressful.

Journey Times

Warriss et al. (1995) studied the effects of journey time on steers (340 kg body weight) by examining a range of physiological and physical responses. It was concluded that journeys of up to 15 hours had no detrimental effects upon the cattle and did not induce untoward fatigue. Later Knowles et al. (1999) compared the physiological and behavioural effects on cattle (steers of 572 kg mean body weight) of transporting them for periods of 14, 21, 26 and 31 hours. The animals were given a "rest" to eat and drink after 14 hours. It was proposed that the findings indicated that journeys of 31 hours duration were not excessively physically demanding. It was observed, however, that many of the animals chose to lie down after approximately
24 hours. Many animals did not choose to drink during the rest stop. Physiological measurements made after the journeys indicated that 24 hours in lairage, with hay and water freely available, allowed the animals to recover substantially, although not completely, irrespective of the journey time.

Malena et al. (2006) studied the effects of both travel distance and the season of the year on the mortality rate in fattened cattle during transport to slaughter in the Czech Republic over a 7 year period. The mean mortality rate was 0.007% ± 0.003%. However, it varied significantly with the travel distance to a slaughterhouse, ranging from 0.004% at a travel distance up to 50 km to 0.024% ± 0.027% at a travel distance over 300 km. The highest mortalities were observed in summer and winter as opposed to spring and autumn. Thermal stress under more severe weather conditions was thought to be the cause of this distribution. The increasing travel distance and the transport of cattle in summer or winter months resulted in an increase in transport-induced mortality rates.

Vecerek et al. (2006a and b) have analysed mortality in transit data for dairy cows transported to slaughter in the Czech Republic over a 7 year period. The effects of travel distance and season were determined. The overall mortality on transit rate was 0.038%. The losses were influenced by distance travelled, from 0.013% for trips not exceeding 50 km, to 0.183% for trips longer than 300 km. The data revealed an undesirable long-range trend of rising dairy cow mortality in all travel distances.

Vecerek et al. (2006c) have characterised the effects of calf diseases on the mortality rate in transit to slaughter over a 7 year period in the Czech Republic. The study also addressed the impact of journey duration. Records from the survey included the numbers of calves that died in transport and the numbers of diseased calves transported for emergency slaughter and the associated mortality in transit. The calf mortality rate in connection with transport overall was 0.026% and for emergency slaughter was 3.266%. The effect of the journey distance on calf mortality indicated that during transport up to 50 km the rate was 0.019% for standard slaughter and 3.029% for an emergency slaughter. For journeys of 200 km or greater the in transit mortality was 0.110% for standard slaughter and 5.177% for an emergency slaughter. Calf health status was reported to have a major impact on transport mortality and an important interaction with journey duration.

Schwartzkopf-Genswein et al. (2007) have addressed the topic of pre-transport management and conditioning upon the responses of beef calves to commercial transport. The interaction between pre-journey handling and journey time was examined. Short (4 hours) and long journeys (15 hours) were studied. It was concluded that pre-conditioning was beneficial for calves pre-transport in that they were better able to tolerate the stressors of transport and handling. In addition, the combined effect of conditioning and short-haul transport was least stressful.
Conditioning had some positive effects on the performance and well-being of transported calves and should be considered when preparing calves for sale and transport.

Warren et al. (2010) have undertaken an audit of transport conditions and arrival status of slaughter cattle shipped by road in Canada to a single processor. The collected data included length of time in transit; temperature variation; season; weather transport conditions; cattle weight; sex and whether sexes were separated on mixed loads; number of lots and whether lots were separated; cattle unloading speed; cattle handling score; driver training and experience hauling cattle; ventilation; and condition of cattle at arrival. The study examined over 50,000 animals on 1300+ journeys All but 0.2% of trucks arrived within the 52 hours allowable transport time before unloading required for rest, feed, and water. Most trucks (85.7%) were from within 8 hours of the plant. Trucks surveyed were at or above the recommended space allowance 49% of the time. There were few non-ambulatory or dead animals encountered in this sample. It was concluded that there were very few visible animal welfare concerns associated with the transportation of slaughter cattle in the population sampled.

Nielsen et al (2011) have reviewed the “Road transport of farm animals: effects of journey duration on animal welfare. The review attempted to distinguish between aspects, which will impair welfare on journeys of any duration, such as those associated with loading, and those aspects that may be exacerbated by journey time. Four aspects of animal transport have been identified, which have increasing impact on welfare as transport duration increases. These relate to (i) the physiological and clinical state of the animal before transport; and – during transport – to (ii) feeding and watering; (iii) rest and (iv) thermal environment. It is thus not journey duration per se but these associated negative aspects that are the cause of compromised welfare. It was suggested that with a few exceptions, transport of long duration is possible in terms of animal welfare provided that these four issues can be dealt with for the species and the age group of the animals that are transported.

Chulayo et al. (2016) determined the effects of distance travelled and lairage duration on the some biomarkers of stress in transported beef cattle in South Africa. Animals transported for distances between 200 and 400 km had appeared to exhibit less physiological stress than those transported between 400 and 800 km and for less than 200 km. Longer lairage durations resulted in increased levels of stress bio-markers.

Simova et al. (2017) proposed that the number of animals that die during transport to a slaughterhouse or shortly after being delivered to a slaughterhouse may serve as an indicator of animal welfare during transport. In this context a study by these authors examined the effects of journey length on mortality rate in cattle resulting from transport to slaughter in the Czech Republic in the period from 2009 to 2014. Journey lengths were categorised as up to 50km, 51–100 km, 101–200 km and over 200km. Higher mortality rates occurred with shorter travel distances (<50km and 51–100km) when compared to longer travel distances (101–200 km and>200km), with a significant difference ($p<0.01$) between short and long travel distances being found in feeders and dairy cows. The season of the year also had a significant impact on the mortality rate among transported cattle. The highest mortality rate in all categories was observed in spring months. The lowest mortality rate was found in autumn months for fat cattle and dairy cows and in winter months for feeder cattle and calves.

> There is little evidence that journey duration, per se, has a detrimental effect on cattle welfare with no differences in the behaviour or physiology of animals being found between transport of 14 and 31 hours. However, this interacts with journey length (higher mortality seen with long journeys) and season (higher in spring and summer than autumn and winter).

Long Journeys

Alam et al. (2010) studied the effects of long distance transport on blood parameters in cattle and water-buffalo transported from India to a livestock market in Bangladesh. The measured variables were selected to reflect frequency of dehydration, metabolic depletion and muscle injury or activation in the animals to assess impacts on animal welfare in transit. It was evident that the long distance export trade was associated with dehydration, lipolysis and muscle injury or activation. It was recommended that both cattle and water buffalo be given adequate feed and water whenever they are off-loaded from vehicles during the course of journeys.

The effects of long journeys comprised of both road and sea transportation phases and rest stops in specified control posts upon physiological responses of weanling heifers and weanling bulls have been described by Earley et al. (2012). The measured response variables included interferon-c production, cortisol, protein, urea, white blood cell numbers and differentials, and acute phase proteins (haptoglobin and fibrinogen) and were used to evaluate the welfare status of animals, before, during and after the respective transport journeys. Age-matched control animals were blood sampled for the same measurements at times corresponding to the times for transported animals. Heifers transported to Spain lost 7.6% of their initial live weight during the sea crossing to France. However, by the time of their arrival in Spain they had regained 3.3% of their initial live weight and had fully recovered to their pre-transport live weight values within 6 days of arriving in Spain. Weanling bulls lost 7.0% of their live weight during the sea crossing from Ireland to France. The live weight loss in control animals ranged from 1% to 2% during the same period. While transient changes in physiological, haematological and immunological variables were found in the transported and control animals relative to baseline levels, the values were within the normal physiological range for the age and weight of animals involved. Physiological measurements made after the road and sea journeys indicated that the 24 hours rest in the lairage, with hay and water freely available, allowed the animals to recover substantially.

Gonzalez et al. (2012) have examined the effects of long haul (>400 km) on aspects of animal welfare in cattle in North America. The study quantified the relationships between transport conditions and the incidence of dead, non-ambulatory, and lame cattle. It was concluded that cull cattle, calves and feeders appeared to be more affected by transport based on the likelihood of becoming non-ambulatory and dying within a journey. It was proposed that the most important welfare concerns during long distance transport are total journey duration, inappropriate space allowances, thermal stress, and the experience of the truck drivers.

Marques et al. (2012) compared the effects of 24 hours of transport with 24 hours of food and water deprivation. That study concluded that the 2 treatments elicited similar responses in terms of acute-phase protein reactions and reduced feedlot receiving performance of feeder cattle. It was proposed that feed and water deprivation are the major contributors to the overall effects of long distance transport on feeder cattle.

In support of current practices and legislation there is evidence that the 24 hours rest in the lairage, with hay and water freely available, allowed the cattle to recover substantially following long journeys.

Calves

Bernardini et al. (2012) have examined the effects of long-distance road transport (19 hours, from Poland to Italy) during 2 seasons (summer vs. winter) on clinical and haematological variables in calves (80 kg / 37 days of age). The effects of thermal loads were examined by correlation with a temperature humidity index (THI) for each journey. Measurements included body temperature, heart rate and range of blood derived biomarkers of stress and metabolism. Animals were sampled at the origin, during the journey and at intervals post-transport. Within the observed temperature-humidity index (THI) range (30 to 80), effective thermoregulation allowed the calves to maintain their body temperature with small physiological changes to prevent thermal stress, particularly in the summer. There were indications of physiological stress associated with loading and unloading. The haematological variables indicated a moderate effect of transport on the hydration condition, reactive and muscular systems, and metabolism. The changes in the clinical variables were similar for both seasons even though in the summer, haematocrit, urea and total protein increased and glucose concentration decreased. It was concluded that the data did not show a pronounced effect attributable to the season of the journey. Long distance road transport leads to notable changes in clinical and haematological variables at the end of the journey. However, these variables remained within their physiological ranges and returned to basal values within a few days after the journey.

Takemoto et al. (2017) have described a study characterising the effects of long distance transport on serum metabolic profiles in steer calves. Non-targeted analysis of serum concentrations of low molecular weight metabolites was performed by gas chromatography mass spectrometry. Transportation affected 38 metabolites in the serum. A pathway analysis suggested that 26, 10, and 10 metabolic pathways were affected immediately after transportation, and 3 and 7 days after transportation, respectively. Some pathways were disturbed only immediately after transportation, which is likely because of feed and water withdrawal during transit. Nicotinate and nicotinamide metabolism, and citric acid cycle were affected for 3 days after transportation, whereas propionate metabolism, phenylalanine and tyrosine metabolism were affected throughout the experiment. These results suggested that many metabolic pathways had marked perturbations during transportation.

Metabolites such as citric acid, propionate, tyrosine and niacin can be candidate supplements for mitigating transportation-induced adverse effects.

Calves can be successfully and safely transported in the range of THI from 30 to 80 as effective thermoregulation allowed the calves to maintain their body temperature with small physiological changes to prevent thermal stress.

Rest Stops

Current livestock transport regulations (EC 1/2005) require that during mandatory rest stops on long journeys (> 8 hours) animals are unloaded for rest and to be fed and watered. There is little evidence published to suggest how these practices might be best managed. The effects of rest stops during long distance transport on the performance and acute phase proteins of cattle have been studied by Cooke et al. (2013). Comparisons were made in terms of responses of steers and heifers exposed to no transport, continuous transport (1,290 km) or interrupted transport (1,290 km with 2 rest stops of 2 hours duration at 430 km intervals). Hay and water were supplied ad libitum to the unloaded animals during the rest stops. It was concluded that inclusion of rest stops during a 1,290 km transport prevented the increase in circulating cortisol and alleviated the NEFA and haptoglobin response elicited by transport, but did not improve feedlot receiving performance of transported cattle.

Ross et al. (2016) have described a study in which available feeding space at commercial rest facilities affected eating behaviour and general activity. Behaviours monitored included eating, drinking, lying, or ‘other’. Doubling feeding space increased the mean proportion of cattle eating by 30%, decreased interruption of eating bouts and had no effect on drinking and lying behaviour. It is proposed that increasing access to feed has the potential to improve welfare and health of transported cattle.

The impact of rest stops on long journeys on indicators of welfare in transported newly weaned calves has been investigated by Marti et al. (2017). After a 15 hour journey the responses of calves to rest periods of 5, 10 and 15 hours with ad libitum access to feed and water were compared with control calves (no resting time) remaining on the vehicle. Following each rest period, calves were reloaded onto the same trailer and taken on another 5 hour journey, before they were unloaded at the same feedlot, for a total transport event lasting 20 hours. Control calves did not have access to feed or water until the end of the 20 hours transit event. Physiological measurements included saliva and hair cortisol, complete blood cell count, serum NEFA, haptoglobin, and substance P concentrations. Behaviours were recorded also. The results indicated that rest stop periods of ≥ 10 hours did not prevent short- and long term stress after transport in weaned calves.

A key issue is the provision of water or feed to young or unweaned calves during transportation and at control posts on long journeys. The method of delivery of water or milk and the frequency at which they should be supplied must be considered. There is evidence that calves may require feed and water every 8-9 hours and thus under current regulations it would be essential to provide these resources during a mid-journey break on journeys adhering to a 9-1-9 schedule.

Repeated Transport

Adams-Proger et al. 2015 have studied the effects of repeated transport in calves. 4 month old steers were transported for 6 hours once a week for 5 weeks. The study concluded that calves exposed to repeated-transport decrease feed intake compared to non-transported calves as an initial response, but overall feed conversion was unaffected and these Holstein calves may have quickly acclimated to repeated transport.

Price et la. (2015) have attempted to examine the physiological and metabolic responses of gestating Brahman cows to repeated transportation. The complex design of the study has rendered the findings difficult to interpret clearly but it is suggested that the results demonstrate that temperament influences physiological responses to stress in gestating Brahman cows. The repeated transport in the study is confounded with day of gestation, seasonal changes, and learning from repeated handling and transport.

Markets

Weeks et al. (2002) examined the design of markets and attempted to identify design features and practices that might underlie or contribute to carcase bruising in cattle. The study surveyed almost 50,000 carcases and reported bruising in 4.1%. The findings indicated that carcase bruising in young bulls was less than in heifers and steers. The study identified a range of design faults including inappropriate right-angled bends in races, dead ends, flooring with insufficient slope or grip, and steps that all potentially contributed to injuries and bruising. Sliding gates were often misused for goading cattle. Projecting fittings and square-edged corners were potentially injurious; conversely, rounded posts and curved races assisted the flow of cattle with minimal impacts. Handling practices were reported as frequently being inappropriate with misuse of goads or prods. Carcases of cattle from markets had a greater incidence and severity of bruising than those arriving directly from farms or dealers.

Handling of cattle at markets presents welfare issues in terms of incidence and severity of bruising. This should be revisited in future work, as there is a general lack of information on the welfare impacts of markets.

Means of Transport

White et al. (2009) have reported an association between position on the vehicle and the effects of transportation on health status and subsequent performance. In general, negative effects were seen in pen locations in which more calves were carried but the effects were not associated with stocking density per se. It was speculated that positional effects on internal environment and interactions with calf behaviour may be responsible.

Gebresenbet et al. (2011) have characterised the vibration levels and frequencies on animals and transport vehicles during journeys. A commercial vehicle carrying dairy was driven at 30, 50, 70 or 90 km h^{-1} on three road types. The effects of cow standing orientation on vibration were examined. The highest level of vibration observed on animals was 2.3 ms^{-2} when driving on gravel roads at 70 km h^{-1}. Vibrations in the horizontal and lateral directions were lower on animals positioned perpendicular to the direction of travel than on those facing forward. Both road conditions and standing orientation had significant effects on vibration levels. Comparison with established exposure limits for humans suggests that the conditions reported may represent a risk to animal welfare.

Werner et al. (2012) have studied the long distance transport of calves in Chile and have concluded that as geographical and economic consideration limit changes in journey duration and other strategies it is recommended that conditions of transported calves should be improved by using specialised livestock vehicles that can provide more comfort, as well as access to water and food during the journey.

Vibration in transit may be an important factor in animals' response to transport in general in relation to fatigue and postural stability. The limited literature available indicates that vibrations in the horizontal and lateral directions were lower on animals positioned perpendicular to the direction of travel than on those facing forward. Both road conditions and standing orientation had significant effects on vibration levels.

Transport and Disease

Thomsen and Sørensen (2013) have examined the effects of short-term road transport on dairy cow welfare. The specific question addressed was whether transportation induced post-transport lameness in cows that were previously not lame. The study included 203 cows from 18 different Danish farms. Cows were locomotion scored and sample cows were selected for transport. Animals were transported on average 84 km (1 hour 55 minutes) using a route simulating typical transportation of cows to slaughter.

Locomotion score did not change significantly and no cows became lame as a consequence of the transport.

Wernicki et al. (2014) evaluated immune and oxidative parameters as indicators of the influence of stress on the occurrence of respiratory syndrome in feedlot calves. Following transportation to a feedlot the calves were studied for a period of 28 days. The calves showed a decrease in feed consumption during the first 7 days at the feedlot. The plasma concentration of thio-barbituric acid reactive substances (TBARS) increased ($p < 0.05$) on days 1 and 3. IgM (immunoglobulin M) concentration was found to be considerably lower on days 14 and 28. Serum haptoglobin level showed a significant increase in stressed calves on days 1, 3, 7, and 14 of the feedlot. Based on these results, it was suggested that stressors associated with transport and adaptation to the feedlot induce a stress reaction in calves, resulting in behavioural disorders, reduced weight gain, suppression of the humoral immunity and increased morbidity during the first weeks.

Earley et al. (2017) have asserted that the association between transportation and the occurrence of the bovine respiratory disease complex (BRDC) in calves has long been recognised. Many hypotheses regarding this association have been declared through the past decades, and it is agreed upon by most researchers that the multiple stressors that calves experience during transportation result in an overall immunosuppression that allows the respiratory tract to be invaded by numerous opportunistic pathogens. As beef calves are typically weaned immediately before loading on to trucks for transport to other locations for fattening, including long export journeys, assessment of the associated stressors on neutrophil function, gene expression and hormonal stress profiles should be investigated further.

Stressors associated with transport, in newly weaned beef calves, are associated with immunosuppression, reduced appetite, initial weight loss and greater vulnerability to disease, particularly respiratory disease.

Sea and Air Transport

Norris et al. (2003) conducted a survey to establish the death rate and the causes of death in cattle exported by sea from Australia. The death rate was 0.24% among 4 million cattle exported, and a greater proportion of deaths occurred on voyages to the Middle East than to South East Asia. The risk of death on voyages to the Middle East was three times greater for cattle exported from southern ports in Australia compared to northern ports. The main causes of death were heat stroke, trauma and respiratory disease. It was concluded that cattle have a low risk of death during sea transport from Australia. The risk of death can be reduced on voyages to the Middle East by preferentially exporting cattle from northern ports, and selecting those with a higher Bos indicus content whenever possible.

Norton et al (2013) have employed Computational Fluid Dynamics (CFD) to characterise the ventilated performance of a livestock vehicle whilst being carried on the car deck of Ro-Ro ferry. The vehicle carried 66 young cattle (approximately 12 months old, liveweight 300 kg) and the ferry crossing formed part of an export journey from Ireland to Spain. The stocking density on both decks was the same at 1.2 m^2 animal $^{-1}$ with 33 animals per deck. CFD was used to analyse the influence of a wind-free environment on the ventilated performance of the livestock transport vehicle. The livestock transporter under investigation had two decks, the top deck of which was naturally ventilated container and its lower deck was mechanically ventilated container. Using CFD the level of environmental heterogeneity was studied in both the mechanically and naturally ventilated decks. It was concluded that the environment in the mechanically ventilated deck exhibited a great deal of environmental heterogeneity owing to its configuration resembling that of a tunnel ventilated structure. Such heterogeneity can cause a build-up of moisture and airborne contaminants on the outlet end of the container and therefore may add additional stresses to the transported animals. The naturally ventilated deck was found to perform well in still conditions, with the unsteady nature of the indoor flow-field providing sufficient fresh air to all of the animals throughout the container. It is suggested that further characterisation and analysis of vehicle thermal micro-environments during sea transport is necessary.

The limited literature available suggests that the environment in mechanically ventilated decks or vehicles will exhibit a great deal of environmental heterogeneity. Such heterogeneity can cause a build-up of moisture and airborne contaminants on the outlet end of the container and therefore may add additional stresses to the transported animals. Naturally ventilated decks or systems may perform well in still conditions, with the unsteady nature of the indoor flow-field providing sufficient fresh air to all of the animals throughout the container. It is suggested that further characterisation and analysis of vehicle thermal micro-environments during sea transport is necessary. Current evidence does not support the use of sea crossings

Space Allowance and Stocking Density

Lambooij et al. (2012) have investigated the effect of the space between the withers of transported cattle and the compartment ceiling on freedom of movement. The investigation was based on physical, biochemical and behavioural measurements during commercial transports. Ceiling heights were set at 10, 15 or 20 cm above the withers for adult dairy cattle and Rose veal calves and 40 cm for pregnant heifers. It was suggested that it might be possible with a clearance of more than 20 cm above the withers to decrease the period of head-butting in cattle. Rectal temperature, heart rate and blood parameters i.e. indices of stress were not affected by ceiling height.

Gonzalez et al. (2012b) have undertaken a survey to characterise the space allowance in cattle during commercial long distance transport in North America Over 6000 journeys were examined all with travel distances of over 400 km. The data gathered included animal numbers transported and body weights and distribution of cattle by trailer compartment as well as the characteristics of the transport vehicles used. Space allowance (SA; m^2/ animal), allometric coefficient (k = SA / $BW^{0.6667}$), and the percentage of deviation from recommended SA (DRSA; %) in the Canadian Codes of Practice were calculated for each compartment of the trailers. Total loaded weight increased and the number of animals decreased with increasing body weight (BW) of the animals. Space allowance, *k*-value, and DRSA were least for calves and feeders compared with fat and cull cattle. Many factors contributed to the variability in space allowance such as body size (smaller animals are placed more densely), compartment of the trailer and number of axles on the vehicle.

Data support using allometric equations, relating body voume to mass, to calculate space allowance for cattle. Horned cattle require 7% more space than polled/dehorned cattle. Cattle require 20 cm headroom above the withers of the tallest animal to reduce aggression and bruising.

Thermal conditions and Ventilation

Theurer et al. (2013) examined the effects of transportation during periods of high ambient temperature on physiological and behavioural responses in beef heifers. The animals (220 kg body weight) were transported for approximately 500 km in conditions where ambient temperature was at or above 32°C. Data from transported animals were compared to un-transported controls. Each group was transported twice after a one week interval. It was concluded that transportation during periods of high ambient temperatures caused only transient changes in physiological and behavioural indices of beef heifers.

Norton et al. (2013) employed computational fluid dynamics (CFD) to analyse the ventilation performance of a livestock transport vehicle in a wind-free environment, such as that presented when the vehicle is transported on the car-deck of a RO–RO ferry. The livestock transporter employed consisted of two decks. The top deck was a naturally ventilated container and the lower deck was mechanically ventilated container. Using CFD the level of environmental heterogeneity was studied in both the mechanically and naturally ventilated decks. It was found that the naturally ventilated container was hotter and more humid than the mechanically ventilated deck. However, the environmental variables were much more evenly distributed in the naturally ventilated container.

Goldhawk et al. (2014a) have characterised the thermal microclimate inside the vehicles during commercial transportation of feeder cattle in Canada and assessed the relationships of the conditions with animal welfare indicators. Journeys of mean duration 18 ± 4.5 hours in summer and winter seasons were studied. Measurements of temperature or humidity at ceiling or animal level did not vary with transportation factors. Temperature and humidity ratio was greater at animal-level than ambient conditions during non-highway travel and stationary periods ($p < 0.01$). During the 3 time periods evaluated within journeys, there was a larger difference between animal-level and ambient conditions during the winter than during the summer ($p < 0.01$). Animal-level temperature‑humidity index (THI) events (consecutive observations of THI greater than 78°F) were more likely to last for longer than 1 hour when the trailer was stationary. Despite an association between indicators of calf welfare and microclimate, all the cattle arrived in good condition. In this reported trial transportation did not appear to cause distress according to the criteria of animal welfare that were assessed. Goldhawk et al. (2014b) have examined also the vehicle thermal micro-climate and animal welfare during the winter transport of beef calves in Canada. Twenty four commercial loads were evaluated for associations among transportation factors, in-transit microclimate, and calf welfare. Transport factors evaluated included vehicle speed, space allowance, compartment within trailer, and transit duration. Calves were transported for 7 hours 44 minutes ± 4 hours 15 minutes, with space allowances ranging from 0.56 to1.17 m^2/animal. Calves arrived in generally good condition on all the journeys and the biochemical biomarkers did not exhibit any major changes that might have been associated with altered welfare status of the calves. It was suggested, however that the results indicated that in-transit microclimate may be a risk factor for post-transport treatment for disease.

Goldhawk et al. (2015) have characterised trailer thermal conditions during winter transport of cattle in Canada. The study attempted also to evaluate indicators used to assess the welfare of cull beef cows before and after transport. Consignments of cull beef cows were studied under winter conditions in Canada. Temperatures and humidities were mapped on the vehicles and related to events during loading and unloading and animal condition and bruising at slaughter. Temperatures were higher within trailers than at ambient locations during both travel and stationary periods. Modifying air inlets by "boarding" was associated with smaller differences in trailer temperature, compared with ambient conditions, while the trailer was traveling at highway speeds versus when trailers were stationary. Moisture levels within trailers were not different from ambient conditions when loads using "boarding" were travelling whereas loads without "boarding" had a larger difference. The moisture within trailers relative to ambient conditions increased when trailers were stationary compared with traveling when “boarding” was used. The majority of cattle transported were in good body condition and had calm temperaments. Increasing the duration of waiting to unload increased the incidence of severe bruising. It was suggested that “boarding” may increase ventilation within trailers during travel and decrease ventilation during stationary periods.

Simova et al. (2017) report that season of the year had a significant impact on the mortality rate among transported cattle. The highest mortality rate in all categories was observed in spring months. The lowest mortality rate was found in autumn months for fat cattle and dairy cows and in winter months for feeders and calves. The implication of the findings is that effective temperature in the vehicle and thermal stress may be a key risk factor for mortality in transit for all categories of cattle.

Ventilation in vessels transporting cattle should have capacity to prevent excessive heat load, using mechanical ventilation if necessary.

Welfare Indicators and Outcomes of Transportation

Arlington et al. (2003) characterised the acute phase protein response in newly weaned calves following transportation for 3 hours with or without co-mingling. It is proposed that the selected acute phase protein may be useful indicators of transport stress in claves on future studies.

Chirase et al. (2004) have determined the effect of transport stress on respiratory disease, serum antioxidant status, and serum concentrations of lipid peroxidation biomarkers in beef cattle. The study examined the effects of 20 hours (2000 km) of transportation upon steer calves (200 kg body weight). The biomarkers employed were serum total antioxidant capacity (TACA) and serum malondialdehyde (MDA) concentrations. It was concluded that transport stress increased serum concentrations of oxidative stress biomarkers that are related to episodes of BRD and mortality in calves.

Broom (2005) has reviewed the effects of land transport on animal welfare. Factors affecting the welfare of animals before, during and after transport which are:- definition of the responsibilities and competence, attitudes to animals and need for training of staff; planning of journeys and methods of payment of staff; laws and retailers' codes; genetics, especially selection for high productivity; rearing conditions and experience; the mixing of animals from different social groups; handling and loading procedures; driving methods; space allowance; increased susceptibility to disease and efforts to minimise the spread of disease.

Pregel et al. (2005) have studied antioxidant capacity as a reliable marker of stress in dairy calves transported by road. Calves (1-2 months old) months were transported by road for 5 hours (approximately 330 km). The overall anti-oxidant capacity consisting of a pool of non-enzymatic antioxidants, such as glutathione, α-tocopherol, β-carotene and uric acid was determined before and after journeys. It was reported that antioxidant capacity is a sensitive and reliable marker to detect changes in oxidative stress in vivo, and can be used to evaluate the effect of treatments when the results are expressed as change with respect to the basal value. Antioxidant capacity on a herd basis may be a useful indicator of animal welfare and may be more sensitive and reliable than the measure of a single parameter, which could reveal individual variations

Buckham-Sporer et al. (2008) have proposed a number of physiological biomarkers that might be useful for the assessment of stress imposed in transit in young beef bulls. The measured biomarkers in included indicators of stress, protein metabolism, tissue damage, acute phase responses and steroid secretion. Specifically the biomarkers were albumin, globulin, urea, total protein, creatine kinase, *β*-hydroxybutyrate, haptoglobin, fibrinogen, cortisol, dehydroepiandrosterone (DHEA), cortisol: DHEA ratio, testosterone, progesterone and total leukocyte count. It was concluded that there was also an effect of breed for all variables except plasma urea, creatine kinase, and testosterone, perhaps indicating that a genetic component contributed to the physiological response to transportation stress, although without any clear trend. Taken together, this profile of physiological variables in the circulation of transportation-stressed bulls may aid in the future detection of disease-susceptible cattle after transportation.

Riondato et al. (2008) reported the effects of road transportation of calves on circulating lymphocyte populations and their subsets to evaluate possible use as stress biomarkers. Following transportation a decrease in the percentages of all T lymphocyte subsets was evident, while they did not decrease as absolute counts. The proportion of CD21+ cells did not change, indicating that the relative reduction of T lymphocyte subsets was not related to an increase in B lymphocytes. These variations may be due to the increase of a natural killer (NK) cell subset. NK cell expansion, together with increasing lymphocyte count and increasing major histocompatibility complex class II expression, may indicate stress-induced stimulation of the immune system.

Kanematsu et al. (2017) have examined, more recently changes in lymphocyte subsets after short journey (3 hours) road transportation of calves, the findings suggest that CD-NK cells and WC1+γδT cells might offer potential as stress biomarkers for calf transportation.

Fazio et al. (2012) have reported the effects of temperament and prolonged transportation on endocrine and functional variables in young beef bulls. Measured endocrine variables included plasma/serum concentrations of adrenocorticotropic hormone, cortisol, total and free triiodothyronine and thyroxine in addition to measurement of other physiological variables such as functional variables (heart rate, respiratory rate and rectal temperature) in calm and temperamental Limousin young beef bulls. Exit velocity measurement was used to classify bulls' temperament as calm or temperamental. It was reported that longer periods of transportation may reduce the magnitude and duration of the endocrine and functional responses to stress of young beef bulls. Animal temperament impacts upon the responses to stress in transit.

Oliveira Paes et al. (2012) have investigated the use of the leukogram as an indicator of stress following weaning and transportation of calves. Three groups were compared, unweaned calves, newly weaned calves and newly weaned and transported calves (4 hours by road). Weaning and weaning plus transportation induced changes in the leukogram indicative of stress and compatible with the action of adrenaline without changing in the neutrophil lymphocytes ratio (N:L). In the calves exposed to weaning and transport, immediately after transport but not in subsequent days, leukogram changes ($p < 0.05$) were compatible with the action of cortisol, as higher N: L ratio and decreased eosinophil count. It was concluded that, under the conditions of the study, there are changes in leukocytes on weaning and road transport related to the action of adrenaline and road transport, respectively, and that the white blood cell count can be used as an indicator of stress in this species.

Stockman et al. (2011) describe the use of QBA (Qualitative Behavioural Assessment) in the welfare evaluation after transportation of steers on a first journey and then again after 9 successive journeys 15 days later. The QBA data were compared with physiological stress biomarker measures. There was significant ($p< 0.001$) consensus among 40 observers in their assessment of behavioural expression of the cattle. QBA were significantly correlated with core body temperature ($p< 0.01$), heart rate ($p < 0.01$), plasma glucose ($p < 0.05$) and the neutrophil:lymphocyte ratio ($p< 0.01$). QBA appears to be a valid and integrative method of assessing cattle welfare under the conditions tested within the present study. There was significant consensus in the ability of human observers to interpret behavioural expression of cattle during this experiment. In addition, observers could identify differences in behavioural expression between cattle that were naïve versus habituated to transport, and these differences were supported by physiological measurements.

Losada-Espinosa et al. (2018) have presented a review examining 72 identified cattle welfare indicators (CWI) that were classified into four categories (physiological, morphometric, behavioural and meat quality). Their validity and feasibility for use in abattoirs were evaluated as potential measures of cattle welfare during transportation to the abattoir and at the abattoir itself. Several highly valid indicators were identified that are useful to assess welfare at abattoirs, including body condition score, human-animal interactions, vocalizations, falling, carcass bruising, and meat pH. In addition, some intermediate valid indicators are useful and should be investigated further.

The welfare of cattle can be assessed by a range of biomarkers, hormones, functional measures and behaviour. The useful application of QBA (Qualitative Behavioural Assessment) in the welfare evaluation of transportation has also been demonstrated.

PIGS

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). 'Good practices for animal transport in the EU: pigs ' (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have identified the main areas of welfare concern for the transport of pigs (porcine species) and have addressed these through identification and integration of recommendations for good and best practice from scientific knowledge, scientific literature, experiences and information from stakeholders. Hazards characterised as serious for transported pigs include: inadequate ventilation, insufficient space allowance, transport duration, lack of sufficient water during transport, incorrect handling during loading, poor fitness prior to transport, and introduction of pathogens before and during transport and the inappropriate application of resting periods during transport.

It is acknowledged that good preparation and planning are prerequisites to minimise hazards. Moreover, adequate competence is required to carry out planning and preparation as well as handling and transporting the animals. Pigs feel more relaxed and less stressed when handled by staff who understand pig needs and behaviour. Well-trained workers are able to load and unload pigs in a relatively short time without stress, thus minimising the risk of injury, slipping and falling. In addition, good handling has a positive effect on the quality of the carcass and meat. Good handlers are therefore not only aware of the theoretical requirements related to transportation they also have sound practical knowledge of pig behaviour and the way they respond to humans.

Some welfare risks are directly related to the category of pigs to be transported, as differences in age, sex and size may be associated with different welfare needs. Piglets just after weaning have a weight of 5 or 6 kg. They are relatively weak and sensitive to low temperatures. Older piglets weighing 25-35 kg are stronger and better able to deal with long journeys compared to piglets, although perhaps not as well as finishing pigs. Cull sows and boars also require special attention: the reason they are send for slaughter is often related to health problems such as lameness, injuries or disease.

Regardless of the animal category, pigs are better able to deal with transport stressors if they are fit when loading. They must be in good health and grouped in advance in calm conditions. Unacquainted pigs should not be mixed on the vehicle to avoid aggression and injuries. The journey should be as short as possible, but journey length can always be affected by unforeseen events such as traffic jams, accidents or breakdown of the truck. The thermal micro-climate on board the vehicle should stay at an acceptable level throughout the whole journey. Temperature and humidity in particular have profound effects on pig welfare as pigs are unable to sweat and lose heat by that method. Therefore it is essential that moving as well as stationary vehicles have good climate control. The challenge to avoid heat stress is even greater if space allowances are at the minimum required level. Pigs must be allowed to drink at any time during long journeys (> 8 hours). The fasting period prior to slaughter should be carefully planned in relation to the expected length of the journey. To avoid the risk of motion sickness and vomiting, the truck should be driven carefully without abrupt braking or acceleration, particularly around curves and roundabouts. Pigs getting sick during transport may require veterinary assistance and/or euthanasia.

During long journeys animals will get tired and resting periods are required. In control posts and other places where animals are offloaded, pigs should be housed comfortably with appropriate space allowance, in good thermal conditions and allowed to drink and eat according to the expected fasting period. The main factors, concerns and issues relating to the welfare of pigs in the immediate pre-slaughter including transport period have been reviewed by Brandt and Aaslyng (2015).

The transportation of pigs will now be considered under the headings identified above and derived from the structure of EC 1/2005 and associated annexes.

Schwartzkopf-Genswein et al (2012) have reviewed road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: The main effects of loading density, trailer microclimate, transport duration, animal size and condition, management factors including bedding, ventilation, handling, facilities, and vehicle design were summarized by species. The main risk factors listed above all have impacts on welfare (stress, health, injury, fatigue, dehydration, core body temperature, mortality and morbidity) and carcass and meat quality (shrink, bruising, pH, colour defects and water losses) to varying degrees. It was concluded that road transport of livestock is a multi-factorial problem where a combination of stressors rather than a single factor is responsible for the animal's well-being and meat quality post transport. Animals least fit for transport suffer the greatest losses in terms of welfare and meat quality while market ready animals (in particular cattle and pigs) in good condition appear to have fewer issues. More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions. Future research needs to focus on controlled scientific assessments, under North American conditions, of varying loading densities, trailer design, microclimate, and handling quality during the transport process. Achieving optimal animal well-being, carcass and meat quality will entirely depend on the quality of the animal transport process.

Fitness to Travel

Fitness to transport standards and issues relating to cull sows and boars have been reviewed by Grandin (2016). The author concluded that sows and boars that have reached the end of their productive lives have a greater risk of welfare problems. The top two reasons identified for culling boars were obesity and reproductive problems. Sows are most often culled due to lameness, low body condition, or failure to rebreed. The OIE (World Organization for Animal Health) fitness for transport guidelines that would apply to sows and boars were compared with documents from the Canadian Code of Practice, Northern American Meat Institute (NAMI), Defra (Department for Environment, Food and Rural Affairs), U.S. National Pork Board, European Practical Guidelines to Assess Fitness for Transport of Pigs, and U.S. Pork Trucker Quality Assurance. The guidelines had the greatest agreement on the following fitness for transport issues: non-ambulatory, severely injured animals, sows in the last ten percent of pregnancy and sows with uterine prolapses, all of which were deemed not fit for transport. There was less agreement on low body condition. One of the reasons for the lack of agreement is that there were stakeholders who specialised in transporting and processing extremely thin animals. A standard that would severely restrict the transport and slaughter of these animals could hinder the business practices of these stakeholders. Many welfare specialists would agree that some of these animals would be unfit for transport.

> There is general agreement that animals that are non-ambulatory, severely injured, sows in the last 10 percent of pregnancy, sows with uterine prolapse and very thin animals are not fit to travel.

Feed and watering intervals

Garcia et al. (2016) have examined the effects of the provision of feed and water on the physiology and behaviour of piglets during a long (32 hour) road journey. The study was undertaken in autumn in the USA and addressed the combined impacts of weaning and long distance transport on the well being of the piglets. The treatment groups included pigs neither weaned nor transported, weaned pigs transported and provided with feed and water, weaned pigs transported without feed and water, weaned pigs transported with only feed and weaned pigs transported with only water provided. The effect of transport (with and without feed and/or water) on weaned pigs was assessed using behaviour, performance, and physiology. After a 32 hour transport period, pigs transported without water lost markedly more weight than those transported with water. Furthermore, the neutrophil to lymphocyte ratio was markedly higher in male pigs transported without water ($p < 0.05$). Overall, transportation had a negative effect on pig well-being, especially when water was not provided. It was proposed that the study supports the continuous provision of water during long distance transport as required by EC 1/2005.

> Pigs transported without water are more severely affected than transport without food. The recent research supports EC 1/2005 in recommending that pigs should have continuous access to water when travelling, and emphasises the importance of this on long journeys when temperatures are elevated and the risk of heat stress is highest.

La

Weeks et al (2008) have reviewed the welfare of cattle, sheep and pig in lairage, with emphasis on stocking rates, ventilation and noise. It was proposed that appropriate space allowances for animals in lairage are not defined. Space allowances that may be suitable for animals in lairage may be suggested based upon previous studies of animals in transport, lairage and on farm. The longer animals are in lairage the more space they require, in order to be able to get up and lie down and lie undisturbed by congeners. Little work has been done on air quality and air flow characteristics in lairages. The range of ventilation must be sufficient to control levels of toxic or irritant gases such as carbon dioxide and ammonia and to remove excess heat and humidity; the latter being particularly relevant for pig lairages in hot weather. Intensities of sound measured in lairages often exceed 85 dB and there is evidence to suggest that such levels can be stressful especially for pigs; and human shouting appears particularly aversive to animals. Cattle vocalise in response to painful stimuli and to convey information to conspecifics that may be related to fear and distress. There is limited evidence that sheep adapt to continuous sound, provided it is not too loud, but respond to intermittent sounds such as gates banging and human shouting. Vocal communication between sheep may be less important than that between cattle and pigs. Levels of vocalisation are potential indices of animal welfare. Animals' prior experiences and factors such as sex, group size and constitution, pen design, and climatic or environmental conditions affect their welfare and responses to conditions in lairage.

Zhen et al. (2013) studied the effects of different lairage times on pigs following 4 hours of transport under winter conditions. The study assessed welfare primarily through meat quality measures and changes. It was concluded that three hours of lairage was appropriate to reduce pre-slaughter stress and obtain better meat quality. It was proposed that no lairage, or excessively long lairage time, might compromise animal welfare and meat quality.

Roldan-Santiago et al. (2013) investigated the effects of five different periods of ante-mortem lairage without food on the energy metabolism, gas exchange and mineral and blood acid-base balances. The lairage periods were 0, 4, 8, 12 and 24 hours. In all groups, increasing lairage periods triggered a significant reduction ($p < 0.05$) in pH, accumulation of lactic acid and percentage of haematocrit. These findings led to the conclusion that ante-mortem lairage periods of longer than 4 hours cause hyperglycaemia, hypercalcaemia, hyperlactataemia, hyperkalaemia, hyponatraemia, acidosis, and more severe dehydration in barrows (male pigs castrated before puberty).

In control posts and other places where animals are offloaded, pigs should be housed comfortably with appropriate space allowance, in good thermal conditions and allowed to drink and eat according to the expected fasting period. No lairage, or lairage of greater than 4 hours without food causes alterations in metabolism which suggest reduced welfare.

Journey Times and Distances

Berry and Lewis (2001) studied the effects of duration and temperature of simulated transport on the performance of early-weaned piglets. Transport was simulated by placing 17 day old weaned piglets into wooden boxes with a space allowance between 0.18 to 0.36 m^2 per piglet with straw bedding. The simulated transport durations were 0 hours (control), 6 hours, 12 hours and 24 hours and temperatures employed were 20, 25, 30 and 35°C. There was a significant interactive effect between transport duration and temperature upon liveweight change in the first 24 hours in both trials.

The animals that incurred the greatest liveweight deficit after weaning relative to un-transported control groups were predominantly either those that had been transported for 24 hours at high transport temperatures (35 and 30°C) or those transported for 6 hours at 20°C and 35°C.The effect of simulated transport was measureable for up to 5 days post-transport. At 14 days post-transport, there was no detectable influence of transport treatment on feed consumption or weight gain. Whilst the study primarily focussed on warning of the problems that will occur if extreme temperature exposure is coupled to long journey times it may be suggested that examination of the data reveals possible recommendations for both optimum temperatures and travel times for piglets. Thus, the temperatures imposing least stress appear to 25-30°C and preferred journey times should probably be 6-12 hours (or less).

Perez et al. (2002) studied the effects of short journeys (15 minutes and 3 hours) on differential haematology, blood glucose and cortisol and plasma activities of a number of enzymes relating to stress and tissue damage as well as meat quality measures. The study also examined the impact of genotype in terms of stress susceptibility and the halothane gene. It was concluded that under normal Spanish commercial conditions, pigs subjected to short transport showed a more intense stress response and poorer meat quality than pigs subjected to moderately long transport when they were immediately slaughtered on arrival at the slaughterhouse. Transport for 3 hours might have allowed the animals to adapt to transport conditions and then could act as a resting period similar to time in lairage. The effect of transport time on welfare and meat quality parameters was more important than genotype and sex. Nevertheless, from the point of view of blood enzyme activities, genetically stress susceptible females transported for 3 hours were more sensitive to muscle damage.

Verecek et al. (2006) have studied the impact of transport distance and season on losses of fattened pigs during transport to the slaughterhouse in the Czech Republic over a 7 year period. The study gathered mortality data for fattening pigs. The mean pig mortality over the study was 0.107%. Journey distance had a marked effect thus for journeys of up to 50 km the mortality was 0.062% but for journeys in excess of 300 km it increased to 0.335%. Season, and presumably weather and thermal conditions, had a significant effect on mortality also. The highest losses occurred in the summer months, especially in June, July, and August. It is suggested that higher transport distances and elevated ambient temperatures in the summer represent the main threats to pig welfare in transit. The research provides sound data but does not allow clear identification of recommendations or a scientific basis for improved practice or guidelines.

Averos et al. (2007) studied responses in serum stress parameters in pigs transported to slaughter under commercial conditions in different seasons. Two journey times were compared, 1 hour and 13 hours, under winter and summer conditions. Cortisol, glucose, creatine phosphokinase (CPK), lactate dehydrogenase (LDH), albumin and total protein serum concentrations were measured. All variables increased during transport and decreased during lairage. Genetics modulated the effect of the rest of influencing factors, with heterozygous (Nn) individuals showing a more marked response in short and winter conditions, but with lower dehydration levels. It was suggested that under Mediterranean commercial conditions, stress in transported slaughter pigs was largely determined by season and genetics, so that an adaptation of handling procedures to these seasonal variations is crucial if transport stress is to be reduced. In this, and other older studies, the stress sensitivity associated with the halothane gene in commercial pigs is an important factor in determining the outcome and impact of transport of pigs. As this mutation, responsible for high stress sensitivity, has now been eliminated largely that component of this and other similar work has little relevance to today's practice and future policy and strategy.

Werner et al. (2007) have proposed that short as well as long transport durations can affect the welfare of slaughter pigs. The study examined the development of mortality rates both during and after the transport of slaughter pigs, and the incidence of pathological findings, was investigated. The data collected in the study indicated that long journeys of 8 hours duration affected the welfare of animals with increased mortalities and pathological findings during the veterinary inspection at the slaughterhouse, particularly in the summer season but that short journeys of only one hour duration were also associated with increases in these measures. It was emphasised that previous regulations on animal welfare during pig slaughter transport focused only on long-term journeys but that the new results indicated that short journeys can also affect the welfare of the animals.

Malena et al (2007) have compared mortality rates in different categories of pigs and cattle during transport for slaughter. The study focused on losses of pigs and cattle over a 9 year period. Transport-related mortality rates were recorded by species and categories of animals and also for the following travel distances: up to 50 km, 51-100 km, 101-200 km, 201-300 km, and over 300 km. Rates differed according to species and category. The highest mortality rates were found in young sows, sows, and boars (0.26%) followed by fattened pigs (0.11%), excluded dairy cows (0.04%), calves (0.03%), and fattened cattle (0.007%). Significant differences were found among mortality rates. The lowest mortality rates occurred with shorter travel distances (< 50 km and 51-100 km) when compared to long travel distances (101-200 km, 201-300 km and > 300 km), with a significant difference between short and long travel distances being found in fattened pigs, fattened cattle and dairy cows. Mortality rates in animals during transport for slaughter show young sows, sows, and boars to be the most susceptible to transport-related stress, followed by fattened pigs, dairy cows, and calves, whereas the highest resistance was observed in fattened cattle.

Wamnes et al. (2008) have studied the behaviour of early-weaned piglets following transport and have attempted to determine the effects of season and weaning weight. Groups of 17 day old piglets were weaned and assigned to road or simulated transport during summer or winter. Following transport for differing periods (0, 6, 12 or 24 hours), piglets were grouped by weaning weight (light, medium and heavy) in pens of four. Piglet behaviour was recorded on days 1, 4, 7 and 14 after weaning and transport. The results suggested that transport of early-weaned piglets may exacerbate the stress of weaning through additional stress related to factors associated with truck movement, such as noise and vibration, and by imposing an increased risk of dehydration following long journeys (>12 hours). This latter figure may indicate a proposed journey duration limit for early weaned piglets.

Sutherland et al. (2009) have described the effects of variations in the environment, journey duration and type of trailer upon mortality and morbidity (non-ambulatory; non-injured pigs - NANI) in during transport in the USA. It was stated that “many factors, including genetics and their handling before they are transported may be associated with the percentages of dead and NANI pigs during their journey to the slaughterhouse. However, conditions during the journey are also a major factor. Conditions that increase the numbers of DOA and NANI pigs are likely to affect their welfare adversely”. The study demonstrated that temperatures below 5°C (especially when there is no bedding in the trailer) and above 20°C, journeys lasting 30 minutes to 4 hours, waiting times at the processing plant longer than 4 hours, journeys during October, November and December, and transporting trailer loads of pigs of both sexes were all factors that could adversely affect the welfare of pigs being transported to slaughter. Furthermore, these factors did not necessarily affect the percentage of DOA and NANI pigs in the same way. However, other variables that were not measured may have also influenced the percentage of DOA and NANI pigs. The percentage of pigs dead on arrival increased at temperatures above 20°C, and the percentage of pigs unable to walk increased at temperatures of 5°C or below. The journey time and waiting time at the processing plant influenced the percentages of dead and injured pigs and pigs unable to walk. It was proposed that during times when there is a high risk of DOA and NANI pigs, extra measures should be taken to reduce the risk. For example, in the summer, pigs could be transported during the cooler times of the day, and in the winter they could be provided with bedding and the trailers could be boarded; whenever possible, transporting trailer loads of pigs of both mixed sexes should be avoided.

Becerril-Herrera et al. (2010) characterised the changes in blood chemistry associated with the transport of pigs to slaughter on journeys of either 8 or 16 hours. Transportation caused an increase of oxygen consumption and body temperature, a decrease in pH and lactic acid accumulation. Both transportation periods caused higher than normal plasma glucose levels, lactic acidosis and evidence of dehydration. The linear regression analysis for pigs transported for 8 h indicates that the pO_2, lactate and Ca^{++} variables correlated negatively with the pCO_2. Animals transported for 16 hours exhibited negative correlations between glucose, and calcium, haematocrit, lactate and potassium levels. It was concluded that regardless of transport time of 8 hours or above, acidosis, hypocapnia, hypoxaemia, hypernatraemia, hypercalcaemia, hyperglycaemia, lactacidaemia and increased haematocrit levels are all indicators of disruption of physiological homeostasis and suggest significant physiological stress imposed by the process.

The effects of transport time on the welfare of pigs have been addressed by Aradom et al. (2012). Transport durations of up to 12 hours were examined where pig behaviour was recorded in transit. Eighteen measurements were performed during two seasons for 4, 8, and 12 hours of transport time with three replications. Blood samples were obtained before and after transport and from control pigs and meat quality was also measured. It was demonstrated that an increase in transport time from 4 to 8 hours had a higher effect than an increase from 8 to 12 hours on the welfare measures and subsequent meat quality. Most of the values of stress hormones and behaviour increased slightly or remained at a steady state between 8 and 12 hours. The continuous increase in creatine kinase with an increase in transport time noted in this study indicates increasing muscular fatigue, which could be attributed to restlessness and loss of balance behaviours of animals during transport. It was also reported that during summer, loading caused thermal stress.

The effects of transport duration and season upon maintenance behaviour, heart rate and deep body temperature in transported pigs have been described by Goumon et al. (2013). That study evaluated the effects of 3 transport durations (6, 12, and 18 hours) on the physiology and behaviour of pigs in summer and winter in western Canada. Heart rate and gastrointestinal tract temperature (GTT) were monitored from loading to unloading. Behaviour was recorded for pigs in summer and winter. The results suggested that in winter, pigs increased their metabolism and were reluctant to rest on cold floors. Pigs transported for 18 hours in winter showed greater evidence of thirst. It may be concluded that under western Canadian climatic conditions, long transport (18 hours) in cold weather appear to be more detrimental to pig welfare than shorter journeys.

Magnani et al. (2014) have determined the effects of long transport and environmental conditions on behaviour and blood parameters of post-weaned piglets with different reactivity to restraint. Piglets were classified by a back-test involving restraint and measurement of escape attempts. The piglets were classified as high, (HR) or low responders (LR). Piglets were then allocated to other treatments i.e. mixed (M) or mixed at loading (MAL) for transport. The journeys were of 14 hours duration. During transport, truck air temperature, skin temperatures and postural and behavioural occurrences were recorded. Prior to and after transportation, blood samples and body weight were also recorded. Piglets lost 5% of their body weight. Environmental conditions affected slightly the behaviour of piglets which were more active during the first 4 hours of transport. The behaviour of the piglets was significantly influenced by the type of pen since some differences in biting and exploratory behaviours were found in mixed pens. Conversely, no differences were found between HR and LR pens. Significant variations with respect to the baseline levels were found only for glucose, which decreased, and for urea, which increased after the journey as a result of the prolonged fasting. In general, the results suggest that long journeys did not have consistent effects on physiological and behavioural parameters of early-weaned piglets while grouping and mixing procedures may affect how they cope with transport.

Machado et al. (2016) evaluated the effects of transportation distances on the dehydration of pigs transported to slaughter in tropical conditions, examining 350 pig shipments. The results showed a liveweight loss estimated at 12% which was increased gradually as the distance increased and pigs were deprived of food and water for increasing periods. The most cost-effective distance for the pigs' transportation under tropical condition was less than 100 km, when there were no significant weight losses.

The risk factors for pre-slaughter losses (mortality) in Italian heavy pigs have been examined by Nannoni et al. (2017). The study investigated the transportation of over 3 million pigs. The percentage of transported batches of pigs with at least one animal lost pre-slaughter increased during summer ($p < 0.001$). The proportion of pre-slaughter losses was higher when journey lasted more than 90 min ($p < 0.001$) and was positively correlated with transport duration ($p<0.01$). Losses were higher ($p<0.01$) in batches transported at low stocking densities (i.e. when heavier pigs were transported). Batches with lower slaughtering order (i.e. longer lairage time) had higher proportions of losses ($p < 0.001$). Logistic regression analysis showed that the odds of a given batch to have at least one animal lost pre-slaughter were 1.32 times higher for batches slaughtered in summer, 1.54 times higher if journey durations exceeded 90 min, 1.25 times higher for batches with low slaughtering order, and not significantly influenced by stocking density during transport.

Voslarova et al. (2017) examined the effects of transportation or journey distance and season on transport losses in finisher pigs in the Czech Republic in the period 2009-2014. The data demonstrated that the likelihood of death losses in transported pigs increases with increasing transport distance. The transport-related mortality ranged from 0.049% in pigs transported for distances below 50 km to 0.145% in pigs transported for distances exceeding 300 km. Despite a decreasing trend in the mortality of finisher pigs transported for slaughter in Europe, that study suggested that current transport conditions are not efficient at ensuring the welfare of pigs during transport for longer distances and the protection of pigs against the negative impact of extreme ambient temperatures. Further research should focus on developing practical guidelines to improve the welfare of pigs in transit accordingly.

Sommavilla et al. (2017) have studied the effects of the season, travel duration and trailer compartment location on blood creatine-kinase (CK), lactate and cortisol concentrations in transported pigs and assessed their relationships with trailer temperature, heart rate and gastrointestinal tract temperature (GTT), behaviour, carcass damage scores and meat quality. Journey times of 6, 12 and 18 hours were examined. The impacts of factors such as ambient conditions, travel duration and vehicle design/ compartment location upon the measured stress variables were investigated. It was concluded that although increased blood cortisol and CK levels appear to indicate a physical stress condition in transported pigs, the weak to moderate correlations with environmental and other animal welfare indicators suggest that blood stress parameters can only be used as a complementary measurement in the assessment of the pigs' response to transport stress. Increasing journey time was associated with greater elevations of stress biomarkers.

Wirthgen et al. (2018) have studied the effects of transport time, environmental conditions and season on the circulating concentrations of insulin like growth factors and insulin like growth factor binding protein in market weight pigs. Blood was collected from 240 market-weight barrows that were transported for 6, 12, or 18 hours in January or July. IGF-I and -II were detected using commercial ELISAs whereas IGFBPs were quantified by quantitative Western ligand blotting. In addition, established markers of stress and metabolism were studied in the animals. The results show that plasma concentrations of IGFBP-3 were significantly reduced after 18 hours of transport compared to shorter transport durations (6 and 12 hours; $p < 0.05$). The concentrations of IGF-I in plasma were higher in pigs transported for 12 hours compared to shorter or longer durations. Season influenced plasma concentrations of IGFBP-3 and IGF-II. Neither transport duration nor differential environmental conditions of winter or summer had an effect on glucocorticoids, albumin, triglycerides, or glucose concentrations ($p > 0.05$). However, low-density lipoprotein concentrations decreased after 18 hours compared to 6 hours of transport ($p < 0.05$), whereas high-density lipoprotein concentrations were higher ($p < 0.05$) in pigs transported for 12 or 18 hours compared to those transported for only 6 hours. The findings indicate differential regulation of IGF-compounds in response to longer transport duration or seasonal changes and support current evidence of IGFs and IGFBPs as innovative animal-based indicators of psycho-social or metabolic stress in pigs.

Thermal conditions and Ventilation

Sutherland et al. (2009) examined the effects of the environment upon mortality in transit or DOA levels in commercial transportation to slaughter in the USA. The percentage of DOA pigs increased at temperatures above 20°C but surprisingly the relative humidity did not influence the percentage of DOA. It was reported that the travel time and waiting time at the processing plant affected the percentages of DOA.

During journeys lasting more than 4 hours, the percentage of DOA pigs decreased and the critical journey time in relation to DOA appeared to be up to four hours. The type of trailer and the presence of bedding affected the percentages of DOA.

Villarroel et al. (2011) have developed a novel approach and method for the assessment of thermal stress for pigs in transit. The study describes the development and application of time derivatives in air temperature and enthalpy as non-invasive welfare indicators during long distance animal transport. Although upper temperature limits have been established for the transport of pigs in Europe, few indices include relative or absolute humidity maxima or mention appropriate enthalpy ranges. In this study, temperature and humidity were measured and air enthalpy (kg water kg dry air^{-1}) calculated on commercial farms, during seven long distance (>24 hours) journeys and at an abattoir. There was an approximate overlap of data points on the psychrometric charts for each location (farm, transport and abattoir). However, the temperature time derivative (°C s^{-1}) and enthalpy time derivative (kg water kg dry air^{-1} s^{-1}) were up to ten times higher during transport than the corresponding derivatives on the farm or at the abattoir. Post-transport observation of pig behaviour also suggested that journeys with higher temperature or enthalpy time derivatives were more stressed (evaluated as the amount of time they spent resting or drinking). It was concluded that time derivatives of temperature or enthalpy could be used as non-invasive welfare indicators during transport and appear to be much more sensitive than absolute values of temperature or relative humidity.

Zhao et al. (2016) have described the mortality rate of weaned and feeder pigs as affected by road transport conditions. The study was a survey of commercial practices and outcomes over a 2 year period. The study aimed to identify possible causative relationships of the mortality rate of weaned and feeder pigs to road transport conditions. The study compared the effects of pig type (weaned vs. feeder pigs), ambient temperature (<15°C or cool/cold, 15°C to 25°C or mild, and >25°C or warm/hot), travel distance (<600 >km, 600 to 900 km, 900 to 1200 km, 1200 to 1500 km, and >1500 km), and the interactive effects on dead-on-arrival (DOA) and rate (DOA per head loaded, %) were evaluated. The effects of the same variables on post-transport mortality of weaned pigs were also evaluated. Results show that DOA rate was affected by pig type, ambient temperature, and travel distance interactively. Weaned pig DOA rates (mean 0.0333%) tended to be higher than feeder pig DOA rates (0.0243%), and weaned pigs were more vulnerable to transport stress in warm/hot conditions. For weaned pigs, DOA rates were higher with >900 km travel distance (0.0543%) than with <900 km travel distance >(0.0118%) in cool/cold conditions, and DOA rates significantly increased as travel distance increased in warm/hot conditions. For feeder pigs, DOA rates were not affected by travel distance in cool/cold or mild conditions; however, higher mortality rates were found with >1200 km travel distance (0.2717%) than with <1200 km travel distance (0.0315%) in warm/hot conditions. Statistical analysis showed that post-transport mortality rate of weaned pigs was affected by ambient temperature during transport and travel distance interactively for the first one or two weeks after transport. However, it should be noted that the relationship between post-transport mortality and transport conditions could have been confounded by other factors, such as management at the finishing farm.

Voslarova et al. (2017) examined the effects of transportation or journey distance and season on transport losses in finisher pigs in the Czech Republic in the period 2009-2014. The data demonstrated that the likelihood of death losses in transported pigs increases with increasing transport distance. The transport-related mortality ranged from 0.049% in pigs transported for distances below 50 km to 0.145% in pigs transported for distances exceeding 300 km. The impact of external air temperature on the transport-related mortality found in our study clearly shows that current transport practices fail to ensure the welfare of pigs transported under other than moderate weather. Particularly cold temperatures below –2°C were associated with increased death losses in winter transport. Despite a decreasing trend in the mortality of finisher pigs transported for slaughter in Europe, the study suggests that current transport conditions are not efficient at ensuring the welfare of pigs during transport for longer distances and the protection of pigs against the negative impact of extreme ambient temperatures. Further research should focus on developing practical guidelines to improve the welfare of pigs in transit accordingly.

Means of Transport (Trailer Design)

Weschenfelder et al. (2012) determined the effects of trailer design on pig welfare during long distance (7 hours) transport. It was concluded overall that when used for long distance transportation under controlled conditions, the pot bellied trailers produced no major detrimental effects on animal welfare or pork quality. However, it was suggested that the design of all trailer types should be modified to improve the comfort of pigs during transportation, especially ventilation, and ease of pig handling when exiting the trailer (presence of steps and ramps).

Goumon et al. (2013) examined the effects of ramp configuration on ease of handling, heart rate and behaviour of transported pigs at unloading. The studies compared different angles of entrance (AOE) to the ramp (90°, 60°, 30°, or 0°), ramp slope (0°, 16°, 21°, or 26°), and an initial 20-cm step associated with 16° or 21° ramp slopes. Measured variables included heart rate (pigs and handler), unloading time, interventions of the handler, and reactions of the pigs were monitored. It was demonstrated that using a 90° AOE had detrimental effects on ease of handling, heart rate and behaviour. The 0° and 30° angles of entry appeared to improve the ease of unloading, whereas the 60° had an intermediate effect. The 30° AOE appeared to be preferable, because pigs moved at this angle baulked less frequently and required less manipulation than pigs moved with a 0° AOE. The results of the second experiment show that the use of a flat ramp led to the easiest unloading. However, the flat ramp did not differ from the 21° ramp in many of the variables reflecting ease of handling, which may be explained by the difference in configuration between the ramps. The results also show that the use of the steepest ramp slope had the most detrimental effect on all aspects of behaviour. Ramp design in terms of structure, angle and angle of approach should be primary considerations in the design of vehicles and loading and unloading systems.

Torrey et al. (2013) have characterised the effects of season and location on the truck on the behaviour of pigs subjected to 8 hour commercial journeys to slaughter in Canada. Pig behaviour was observed at loading, in transit, at unloading, and in lairage. Handler intervention at loading was observed, and the time to load and unload was recorded. Season did not affect loading time but more interventions were required in summer than winter. Loading in winter tended to be longer into compartments involving internal ramps. In transit, more pigs were standing in winter compared with summer. Unloading took longer in winter than in summer and from compartments where pigs had to negotiate ramps and 180° turns. Furthermore, pigs experienced more slipping, falling, overlapping and walking backwards in summer than pigs in winter. Pigs unloading from compartments with internal ramps slipped more than other pigs. Season influenced latency to rest in lairage, with those transported in summer resting sooner than those in winter. It was concluded that season and location within trucks differentially affect pig behaviour before, during, and after long-distance transportation. Differences in lighting and temperature between seasons and the inclusion of internal ramps within vehicles play important roles in the welfare of pigs transported to slaughter.

Kephart et al. (2014) have studied the efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures. The conditions studied were classified as warm (<26.7 °C) and hot (≥26.7 °C). Four sprinkling methods were compared; no sprinkling, sprinkling of pigs only, sprinkling of bedding only and sprinkling of pigs and bedding. In warm weather, there were no differences between sprinkling treatments for surface temperature, vocalizations, or slips and falls. However, stress signs were 2% greater when sprinkling pigs- or bedding only-compared to control. In warm and hot weather, sprinkling did not affect non ambulatory, dead, or total transport losses. Despite no clear indications of the effects of sprinkling strategy being apparent from this study it was asserted that the inference space of this study is relatively small and so further studies should be conducted to see if these results are applicable to other geographical regions and seasons.

Conte et al. (2015) undertook studies to assess the effects of season, truck type (Double decked (DD) or Pot bellied (PB)), and location in the truck on the gastrointestinal tract temperature (GTT) of market-weight pigs during transport. The studies analysed data from summer and winter transport on 8 hour journeys. Transport was divided into separate periods for assessment i.e. in rest, pre-travel, initial travel, pre-arrival 1, pre-arrival 2, unloading, lairage 1, and lairage 2. The change in GTT (ΔGTT) was calculated as the difference between the measured GTT at any determined event and the GTT measured at rest. The ΔGTT of pigs was greater in summer than in winter and only during the pre-travel and initial travel periods. No difference was observed in the ΔGTT between the 2 truck types. In the first of 2 trials in summer, pigs located in the front top and rear top compartments of the PB trailer presented greater ΔGTT values than those transported in the middle top and front belly compartments during initial travel. In summer, during pre-arrival 1 and 2, a greater loss of GTT was found in pigs located in the rear top compartment of the DD truck compared with the rear lower compartment and in the front middle compartment compared with the rear middle compartment of the PB trailer.

In a second trial, the ΔGTT of pigs was greater in summer than in winter during pre-travel 2. Pigs in the front top compartment had a greater ΔGTT compared with pigs in the middle top, lower deck, and front belly compartments during the pre-travel periods. It was reported that based on the results of the 2 trials, modifications of the PB trailer model are recommended to limit body temperature increase due to physical stress at loading and unloading, and during transport due to inconsistent ventilation rate across vehicle locations.

The effects of truck suspension systems on pig welfare and product quality have been examined by Dalla Costa et al. (2017). It was hypothesised that transport stress may be reduced through a vehicle suspension system that provides a much smoother ride during transport, and consequently is less aversive to pigs. The study compared leaf sprung vehicles with air suspension designs and assessed the pigs' well-being by measures of blood chemistry, behaviour and product quality measures. The suspension type neither influenced pig behaviour in lairage nor blood cortisol and lactate concentrations. However, when compared with the air suspension system, the use of leaf suspension, the leaf suspension system was associated with a greater number of skin lesions in the back and thigh and more meat quality problems than the air suspension. It was proposed that the use of leaf spring suspension system negatively affects the welfare of pigs due to the increased carcass damage and resulted in poorer pork quality traits. Therefore, the use air suspension system may improve carcass and meat quality traits of pigs transported to slaughter.

Arduini et al. (2017) have studied the effects of deck level on the vehicle and environmental conditions (Temperature Humidity Index, THI) on body surface temperature and carcass damage in heavy Italian pigs during short transport journeys (30 minutes). Surface temperatures (maximum values in dorsal and ocular regions of the pigs) were determined by thermal imaging. The highest and lowest body surface temperatures were found in pigs located on the middle and upper decks, respectively. THI class significantly affected skin damage scores, which increased with increasing THI class. Even at relatively low temperatures and THI, the results of this study suggested the need to increase the control of environmental conditions in the truck during short-distance transport of pigs, in order to improve welfare and reduce loss of carcass value.

Transport stress may be reduced through a vehicle suspension system that provides a much smoother ride during transport, and consequently is less aversive to pigs. When compared to air suspension system, leaf suspension was associated with a greater number of skin lesions, and negatively affects pig welfare. This topic should be examined in more details in terms of full elucidation of stress responses associated with vibrations and ride type. The efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures may require further research for application in the UK.

Handling, Loading and Unloading

Geverlink et al. (1998) have studied the effects of lairage sounds and short (25 minutes) transport upon some physiological and behavioural responses of pigs. All sounds were played to the pigs at the same intensity of 85 dB. Pigs exposed to the sounds of machines in lairage spent significantly more time close to their group-mates compared with control pigs, with pigs subjected to the pig sounds when in the "restrainer" being intermediate. Transported pigs spent less time exploring the raceway and were less active than control pigs from the stationary lorry. Heart rate was higher during transport than during the stationary period. In contrast, during unloading, the sound exposure period and the post-sound period, heart rate was lower in the transported groups. Heart rate did not significantly differ between sound treatments. Salivary cortisol concentrations were significantly higher after transport than after the stationary period and remained higher for transported pigs after the sound exposure period. Cortisol levels did not differ significantly between sound treatments. It may be proposed that social support from group mates (unmixed pigs) might be an important factor in determining the effects of stress associated with handling and transportation particularly exposure to novel or unusual sounds.

Broom (2003) has addressed transport stress across species. It was concluded that the welfare of animals during transport should be assessed using a range of behavioural, physiological and carcass quality measures. In addition, health is an important part of welfare so the extent of any disease, injury or mortality resulting from, or exacerbated by, transport should be measured. Many of the indicators are measures of stress in that they involve long-term adverse effects on the individual.

Key factors affecting the welfare of animals during handling and transport are:- attitudes to animals and the need for training of staff; methods of payment of staff; laws and retailers' codes; genetics especially selection for high productivity; rearing conditions and experience; the mixing of animals from different social groups; handling procedures; driving methods; stocking density; increased susceptibility to disease and increased spread of disease.

Bertol et al. (2005) have investigated the effects of feed withdrawal and handling intensity on longissimus muscle (LM) glycolytic potential and blood measurements in slaughter weight pigs (approximately 110 kg). The pigs were used in a randomised complete block design with a 2 × 2 factorial arrangement of treatments: 1) feed withdrawal (0 vs. 24 hours), and 2) handling intensity (low vs. high). Biopsy samples were collected from the LM at the beginning of feed withdrawal, at the end of the handling procedure, and 4 hours after handling. Blood samples were collected 2 hours before and immediately after the handling procedure. There were no interactions between feed withdrawal and handling intensity for any of the variables measured. Feed withdrawal decreased ($p < 0.05$) baseline and post-handling body temperature (38.85 vs. 38.65°C and 39.70 vs. 39.37°C respectively) and blood glucose, lowered baseline partial pressure of oxygen and partial pressure of carbon dioxide, and increased baseline and post-handling plasma free fatty acid concentrations. High-intensity handling produced higher post-handling lactate and glucose, and lower post-handling blood pH (7.33 vs. 7.18 respectively), bicarbonate, base excess and total carbon dioxide than low-intensity handling. Longissimus muscle glycolytic potential of fasted pigs was lower than in fed pigs at the end of the handling procedure (177.2 vs137.0 mol/g of wet tissue respectively). There was no effect of handling intensity on longissimus muscle glycolytic potential. Feed withdrawal did not attenuate the blood acid-base changes caused by handling; however, the combination of feed withdrawal and handling decreased muscle glycolytic potential. It may be suggested that the work supports the development of clear guidelines to ensure that pre and post-transport handling impose minimal stress wherever possible and that guidelines should define best practice based on sound scientific evidence.

Goumon et al. (2013) examined the effects of ramp configuration on ease of handling, heart rate and behaviour of transported pigs at unloading. The studies compared different angles of entrance (AOE) to the ramp (90°, 60°, 30°, or 0°), ramp slope (0°, 16°, 21°, or 26°), and an initial 20-cm step associated with 16° or 21° ramp slopes. Measured variables included heart rate (pigs and handler), unloading time, interventions of the handler, and reactions of the pigs were monitored. It was demonstrated that using a 90° AOE had detrimental effects on ease of handling, heart rate and behaviour. The 0° and 30° angles of entry appeared to improve the ease of unloading, whereas the 60° had an intermediate effect. The 30° AOE appeared to be preferable, because pigs moved at this angle baulked less frequently and required less manipulation than pigs moved with a 0° AOE. The results of the second experiment show that the use of a flat ramp led to the easiest unloading. However, the flat ramp did not differ from the 21° ramp in many of the variables reflecting ease of handling, which may be explained by the difference in configuration between the ramps. The results also show that the use of the steepest ramp slope had the most detrimental effect on all aspects of behaviour. Ramp design in terms of structure, angle and angle of approach should be primary considerations in the design of vehicles and loading and unloading systems.

Berry et al. (2012) have compared loading methods for slaughter pigs. The study examined the effects of a loading gantry versus a traditional chute. The trial reported the effects of the 2 systems, traditional chute (TC) vs. prototype loading gantry (PLG) on welfare at the time of loading and performance measures and transport losses. Two sequential studies examined 571 loads of pigs. Pigs loaded using the prototype PLG experienced fewer total transport losses than pigs loaded using the TC. It was concluded that the prototype loading gantry improved all welfare measures at the time of loading and reduced overall total transport losses. It was suggested that loading systems that improve on-farm swine welfare at loading and reduce transport losses at the processing plant can be designed.

Driessen et al. (2013) have emphasised the importance of training and education in terms of animal handling skills in relation to pig transport. They identify five key areas of focus: 1) driving pigs from the pens via an alley to the trailer, 2) loading, 3) actual transport, 4) unloading to the lairage, and 5) the final phase driving pigs to the stunning. Attention must be paid to design of the facilities to allow optimal handling practices to be applied. An inadequate design and a poor condition of the facilities will negatively affect the ease of handling pigs. Education and training programs have to be repeated regularly so that knowledge can be refreshed.

Goumon and Faucitano (2017) and Faucitano (2018) have reviewed many aspects of handling, loading and unloading for pigs. The procedures discussed include the use of tools, group sizes, use of shipping pens and mixing. Important factors affecting pig behaviour are recognised such as light and sound, and alley and exit design (length, width and shape) and ramp design (bedding, cleat spacing and angle). Evidence is presented illustrating the advantages of using hydraulic decks as opposed to internal ramps (Weschenfelder et al., 2012). Dalla Costa et al. (2016) have compared fixed deck (ramp access only) and hydraulic lifting deck pig transport vehicles in order to evaluate the effects of the loading and unloading system of the vehicle on behaviour, blood parameters. They reported easier and faster loading for the vehicle equipped with the hydraulic system, resulting in lower exsanguination blood cortisol levels in pigs. It was concluded that the use of the vehicle featuring the upper hydraulic deck should be recommended for ease of handling at loading, improving animal welfare and reducing the work load of handlers. Moving pigs to their truck compartment using ramps may also cause (or contribute to) long lasting effects on pigs' stress response as greater proportions of DOA and fatigued pigs on arrival at the abattoir, and greater exsanguination blood cortisol concentrations were found in pigs transported in trailers with internal ramps compared to other vehicle types, equipped with hydraulic decks, such as a double-decked truck or a flat-deck trailer (Ritter et al., 2008a; Sutherland et al., 2009; Kephart et al., 2010; Weschenfelder et al., 2012; Correa et al., 2013, 2014).

Correa et al. (2014) have characterised the effects of season and load location on the welfare of pigs during long distance transport on pot-bellied (PB) vehicles. A key component of the study was to understand the impacts of vehicle design and operation on the pigs. It was concluded that some locations within the PB trailer have a negative

impact on the welfare of pigs at loading and during transport with more pronounced effects in the winter due to the additive effect of cold stress.
Modular systems and chute or gantry loading systems are also useful alternatives to traditional loading systems but require space and additional investment. In all systems the groups of pigs to be loaded should be matched in number and composition to the ramp or chute characteristics e.g. width. For moving pigs, flags, paddles and boards are preferred options compared to electric prods and pigs may show less reluctance to more or board a truck if moving from a darker top a lighter environment.

Goumon and Faucitano (2017) have recommended that "more research is needed to develop a low-stress handling tool to assist loading crews in loading and moving pigs in challenging areas, such as the transition area between the barn and the loading area and loading ramps. Additional research is also required on the interaction between group size and alley/ramp width and to find and implement strategies to reduce fighting in the pen. Further evaluation of the different components of loading chute design (ramp angle, chute width, flooring, lighting, covered vs. uncovered, etc.) and development of alternatives is needed. Novelty is an important factor that makes pigs reluctant to move in the farm alleys and on the truck. More research is required to reduce this effect".

Research supports the development of clear guidelines, based on the scientific evidence, to ensure that pre and post-transport handling impose minimal stress wherever possible.

Long Journeys

Lewis and Berry (2006) have examined the effects of season on the behaviour of early-weaned piglets during and immediately following transport. In North America commercial transport of piglets occurs without supplemental heat, over long durations (24 hours) and without feed and water. In this study scan sampling was used to compare behaviour in transported piglets across seasons (summer, autumn and winter) over representative durations. The journey durations were 0 (control) 6, 12 or

24 hours. Resting behaviour during transport increased with transport time in frequency from 59.8% (1–12 hours) to 91.5% (13–24 hours). This pattern was more defined in winter and autumn implicating cold as a causal factor. Higher levels of post-transport resting in transported (81.4%) compared to control piglets (77.5%) may suggest fatigue is a causative factor. As the duration of transport increased, post-transport drinking frequency increased, although significance was reached between control (2.4%) and 24 hours of transport (3.7%) only. Long transport durations may thus delay hierarchy development, require additional coping strategies with respect to cold and increase the risk for dehydration. During winter transport the frequency of piglet interactions (three piglets) was much lower than in summer (39 piglets) and fall (18 piglets) indicating that the cold temperatures may have affected establishment of a dominance hierarchy. Higher levels of resting for 3 days in winter and 2 days in summer could indicate more post-transport fatigue in these seasons. Transport, irrespective of season, resulted in behaviour indicative of coping strategies. The study suggests that more attention should be paid to behavioural impacts of long distance transport and thermal environments for piglets. However, in the absence of complementary further research it is not possible to make any clear recommendations based on the outputs of this work alone

Weschenfelder et al. (2012) determined the effects of trailer design on pig welfare during long distance transport. It was concluded overall that when used for long distance transportation under controlled conditions, the pot-bellied trailers produced no major detrimental effects on animal welfare or pork quality. However, it was suggested that the design of all trailer types should be modified to improve the comfort of pigs during transportation, especially ventilation, and ease of pig handling when exiting the trailer (presence of steps and ramps).

Mota-Rojas et al. (2012) characterised the effects of long distance transportation and CO_2 stunning on critical blood values in pigs. Pigs were fasted for 8 hours and then transported for 27 hours without feed and water. This fact alone devalues the study when considered in the framework of European Regulations and welfare standards. The pigs were carried at a space allowance of 0.4 m^2 per pig (which might mean a stocking density of 300kg m^{-2} although body weight was not given). However what may be of value is that the study suggested that the sex and physiological status of the pigs affected their responses to the same transport conditions and practices. Thus, overall the results show that both stimuli caused metabolic and physiological disturbance. Gilts were more efficient in controlling glycaemia after a long transport journey (24 hours), than castrated males. Females on arrival had elevated lactate compared to basal levels. Females and entire males were more susceptible to transport stress compared to castrated pigs, and entire males showed more complications restoring the gas exchange compared to females and barrows (male pigs castrated before puberty).

Garcia et al. (2016) have examined the effects of the provision of feed and water on the physiology and behaviour of piglets during a long (32 hours) road journey. The study was undertaken in autumn in the USA and addressed the combined impacts of weaning and long distance transport on the well-being of the piglets. The treatment groups included pigs neither weaned nor transported, weaned pigs transported and provided with feed and water; weaned pigs transported without feed and water weaned pigs transported with only feed and weaned pigs transported with only water provided. The effect of transport (with and without feed and/or water) on weaned pigs was assessed using behaviour, performance, and physiology. After a 32 hour transport period, pigs transported without water lost markedly more weight than those transported with water. Furthermore, the neutrophil to lymphocyte ratio was markedly higher in male pigs transported without water ($p < 0.05$). Overall, transportation had a negative effect on pig well-being, especially when water was not provided. It was proposed that the study supports the continuous provision of water during long distance transport as required by EC 1/2005.

Mortality increases with journey length, with best pig survival, and least weight loss, occurring when journeys are less than 90 minutes or 100 km. Longer journeys are associated with behavioural and physiological indicators of stress and physiological disruption (especially between 4-8 hours of transport), poorer meat quality, greater weight loss and a linear increase in markers for muscle fatigue (creatinine kinase). During long journeys animals will get tired and resting periods are required. On journeys exceeding 24 hours, feed should be available every 24 hours at control posts, followed by 6 hours rest. Studies of long journeys support the continuous provision of water during transport

Space allowance / Stocking Density

Lambooy and Engel (1991) have characterised the effects long distance transport of pigs in relation to stocking density and ventilation. Pigs (110 kg body weight) were transported for 25 hours (11 journeys). Three stocking densities were employed 186, 232 and 278 kg m^{-2}. Two different vehicle ventilation regimes were employed and the impact of showering was studied. The key findings of this study were a proposal that loading density should be limited at about 232 kgm^{-2} (approximately 0.47 m^2 per pig) for animal welfare and meat quality reasons and that strong interactions between transport factors may mask other main effects and that this should be considered when attempting to assess welfare in transit.

Warriss et al. (1998) have studied the effects of stocking density on blood indicators of stress and meat quality aspects in pigs. Pigs were transported for approximately 3 hours followed by 1 hour lairage and were blood sampled at slaughter. Stocking densities employed were in the range 201 to 321 kg m^{-2}. Higher stocking densities resulted in more physical stress to the pigs based on the activity of the enzyme CPK in the blood. Stocking density did not apparently affect psychological stress and high densities did not result in dehydration. The colour, water holding capacity and instrumentally determined texture of the pork from the carcasses of the pigs were not affected by stocking density. The results indicate that the highest stocking density examined (321 kg m^{-2}) is unacceptable for the transport of pigs and thus confirm current legislation and guidelines. The second highest density currently not permissible either (281 kg m^{-2}) was reported as having no adverse effect on the welfare of pigs. It was proposed that higher stocking journeys might be scientifically acceptable for short journeys (3 hours) but not for longer ones where pigs need more space to lie down. This advice is, of course, not pertinent as the current stocking density is limited to 235 kg m^{-2} for all journeys.

The effect of stocking density in transit on the carcass quality and welfare of slaughter pigs has been considered by Guise et al. (1998). The trial examined the effects of transport stocking densities of 201, 241, 281 and 321 kg m^{-2} on carcass quality and some welfare indices. The range of stocking densities studied encompassed the upper level set for 100 kg pigs in European Union legislation (235 kg m^{-2}) and journey duration for the study was 3 hours. Stocking density had no effect on any variables measured and it was thus claimed that there was no evidence that transport stocking density had an effect on the carcass quality or welfare of 95 kg pigs on short journeys

Barton Gade and Christensen (1998) investigated the effects of stocking density on pigs in transit. The range of stocking densities employed was between 200 and 285 kg m^{-2}. The conclusions based on in transit behaviour and postural stability and blood chemistry and carcase damage was that high space allowances could encourage loss of balance and injury. Other factors contributing to some of the outcomes confounded clear recommendation of optimum practice.

Brown et al. (1999) have examined the effects of journey time in pigs by characterising a number of physiological and behavioural responses. Pigs of 80-100kg body weight were transported by road for 8, 16 or 24 hours before a 6 hour lairage period prior to slaughter. Only transport for 24 hours led to losses in carcase weight. The concentration of non-esterified fatty acids increased with the time spent travelling. The concentrations of cortisol, creatine phosphokinase and lactate were all low in comparison with the levels found in commercially slaughtered animals. Plasma albumin and protein concentrations indicated that the animals were becoming dehydrated during the longer journeys. The animals lay down for most of the journey and appeared to be asleep. During the period in lairage, the animals transported for 8 hours had two distinct periods of feeding and drinking but spent most of the time lying down, but those transported for 16 and 24 hours showed far more eating and drinking activity. All the groups appeared tired, but the urge to eat of the groups transported for 16 hours, and especially 24 hours appeared to be more important. There were behavioural and the physiological differences between the transported groups and the controls. It may be suggested that transport for up to 24 hours may not impose severe stress upon mature pigs (in keeping with current legislation and recommendations). Six hours in lairage with access to food and water allowed most of the physiological parameters to return to pre-transport levels. This is consistent with the current requirement and concept of allowing an adequate recovery period with access to feed, water and bedding after a long journey e.g. control post time of 24 hours minimum.

Whiting et al. (2002) attempted to define minimum space allowance for transportation of swine by road. The authors reported that “a maximal loading pressure recommendation for pigs weighing from 5 to 250 kg was derived by a consultative process involving the swine transportation industry, animal welfare groups, and a literature review. It was concluded that the recommended maximal loading pressure under ideal conditions for swine loaded in groups can be described as a Hoerl model:

$$y = (37.53)(0.9969)^{W}(W^{0.5008})$$

where y = loading pressure in kg body weight m^{-2}
and W = average animal body weight in kilograms”.

Comparison reveals that this will yield around 300kg m^{-2} ; which is greatly in excess of the current 235 kg m^{-2} presented in EC 1/2005.

Ritter et al. (2006) have studied stocking density on losses (mortality and non-ambulatory pigs) under US transport conditions. Pigs of 130 kg body weight were transported for around 3 hours in different seasons of the year. The stocking densities used were calculated as 270 and 333 kg m^{-2}. The incidence of losses (dead and non-ambulatory pigs) was determined at the processing plant. Of the 12,511 pigs transported 0.23% were dead on arrival, and 0.85% were non-ambulatory at the plant.

Increasing transport floor space from 0.39 to 0.48 m^2 per pig (333 to 270 kg m^{-2}) reduced the percentage of total non-ambulatory pigs (0.62 vs. 0.27 respectively), non-ambulatory, non-injured pigs (0.52 vs. 0.15 respectively) and total losses (dead and non-ambulatory pigs) at the plant (0.88 vs. 0.36 respectively) and tended to reduce dead pigs (0.27 vs. 0.08 respectively). However, transport floor space did not affect the percentage of non-ambulatory, injured pigs at the plant. The percentage of total losses at the plant was positively correlated to waiting time at the plant, unloading time, and total time from loading to unloading (r = 0.24, 0.51 and 0.36, respectively). Average temperature during loading, waiting at the farm, transport, waiting at the plant, unloading, and average pig weight on the trailer were not correlated to losses. It is proposed that the study confirms that stocking densities of 270kg m^{-2} or less are required to minimise losses caused by transportation. The fact that high losses in this study are still associated with the stocking density of 270kg m^{-2} suggests that the stocking density required in Europe of 235 kg m^{-2} is more appropriate for good welfare.

The effects of distance moved during loading and floor space on the trailer during transport on losses of market weight pigs on arrival at the packing plant have been studied by Ritter et al. (2007). In this study pigs (130 kg body weight) were transported for approximately 3 hours to a commercial processing plant. The losses were recorded at this time (mortalities and non-ambulatory pigs). These data were correlated with characterisations of the distance moved during loading and floor space on the trailer during transport. These parameters were defined according to a convention e.g. distance moved from the pen to the exit of the building (short; 0 to 30.5 m) vs. long (61.0 to 91.4 m) and transport floor space (0.396, 0.415, 0.437, 0.462, 0.489, or 0.520 m^2/pig). These space allowances equate to stocking densities between 250 and 328 kg m^{-2}. Loading distance treatments (subplots) were compared within transport floor space treatments (main plot). The number of non-ambulatory pigs during loading and the number of dead and non-ambulatory pigs at the plant were recorded. Non-ambulatory pigs were classified as fatigued, injured, or injured and fatigued. In addition, the incidence of pigs exhibiting signs of stress (open-mouth breathing, skin discoloration, and muscle tremors) during loading and unloading was recorded. There were no interactions between distance moved and transport floor space treatments.

Moving pigs long compared with short distances during loading increased the incidence of open-mouth breathing after loading (24.9 vs. 11.0 respectively) and tended to increase the incidence of non-ambulatory pigs during loading (0.32 vs. 0.08 respectively;) and of non-ambulatory, injured pigs at the plant (0.24 vs. 0.04 respectively). However, distance moved did not affect other losses at the plant. Total losses at the plant were greater for the 3 lowest floor spaces compared with the 2 highest floor spaces, and pigs provided 0.462m^2 per pig during transport had similar transport losses to those provided 0.489 and 0.520 m^2/pig (total losses at the plant = 2.84, 1.88, 1.87, 0.98, 0.13, and 0.98 of pigs transported, for 0.396, 0.415, 0.437, 0.462, 0.489, and 0.520 m^2/pig, respectively). The study concluded that transport floor space has a major effect on transport losses and suggested that these losses are minimised at a floor space of 0.462 m^2 / pig or greater. This latter figure equates to 281 kg m^{-2} and as this figure is considerably higher than the current European limit of 235 kg m^{-2} then the study offers little to inform future practice, policy or legislation.

Sutherland et al. (2009) have examined space requirements of weaned pigs during a sixty minute transport period in summer. The study employed a range of space allowances of 0.05, 0.06, and 0.07 m^2 per pig with a constant 100 pigs per compartment. Behaviours and postures in transit were video-recorded and scan analysed. Blood samples were collected and body weight and lesion scores recorded. The average trailer temperature during the trial was 28.4°C and relative humidity 60%. Cortisol, haematocrit, blood urea nitrogen, total protein, albumin, aspartate aminotransferase, creatine kinase, and gamma-glutamyl transferase all increased after transport regardless of space allowance. Plasma glucose and body weight decreased after transport regardless of space allowance. Lesion scores increased after transport and were greater for barrows compared with gilts. The neutrophil to lymphocyte ratio was greater for pigs transported at 0.05 m^2 per pig compared with pigs transported at 0.06 and 0.07 m^2 per pig. Pigs transported at 0.05 m^2 per pig lay down less than pigs transported at 0.06 and 0.07 m^2 per pig between 30 and 60 min of transport. Greater neutrophil to lymphocyte ratios and less lying behaviour performed by pigs transported at 0.05 m^2 per pig suggests that a minimum space allowance of 0.06 m^2 per pig was preferable when transporting weaned pigs for 60 min during summer. This recommendation equates to 83 kg m^{-2} for weaner pigs.

Pilcher et al. (2011) have analysed the effects of stocking density or floor space during transport as well as journey time on indicators of stress and transport losses of market-weight pigs. Indicators of stress included open-mouth breathing, muscle tremors, and skin discoloration and transport losses included dead on arrivals, non-ambulatory, non-injured, and non-ambulatory, injured pigs. The study examined 160 loads of market-weight pigs (body weight 124.7kg) using a split-plot design with a 2 × 6 factorial arrangement of treatments where journey time (short (<1 hour) and long (3 hours)) and floor space (0.396, 0.415, 0.437, 0.462, 0.489, and 0.520 m^2 per pig) were considered. Total DOA and non-ambulatory percentage was 0.24%. Neither journey time nor floor space had an effect on the incidence of dead and non-ambulatory, injured pigs, or on total transport losses. There were significant interactions between journey time and floor space treatments for the incidences of non-ambulatory, non-injured pigs and open-mouth breathing. For 2 of the smallest floor spaces (0.415 and 0.437 m^2 per pig), the incidence of non-ambulatory, non-injured pigs was greater on short than on long journeys; for the other 4 floor spaces there was no effect of journey time. The incidence of open-mouth breathing for the 3 smallest floor spaces was greater for short than long journeys, whereas there was no effect of journey time for the 3 greatest floor spaces. The frequency of skin discoloration was greater for pigs transported at the 2 smallest floor spaces compared with the other 4 floor spaces. It was concluded that short journey time increased the frequency of indicators of stress for pigs transported at smaller floor spaces and also increased the incidence of non-ambulatory, non-injured pigs at 2 of the 3 smallest floor spaces. However, neither transport floor space nor journey time had an effect on total losses.

The effects of reduced stocking / loading density on pig welfare on long journeys have been studies by Gerritzen et al. (2013). The current recommended or normal density of 235 kg/m^2 was compared to a lower density of 179 kg/m^2 on road journeys of 550 km. Pig measurements included body temperature, behaviour, heart rate and blood parameters. Throughout the journeys, low density pigs displayed more resting behaviour than normal pigs. Average body temperature was lower for pigs transported at low density than those transported at normal density. During loading heart rate increased in both densities pigs and declined after the vehicle had been closed before departure, but remained slightly elevated in normal density pigs. Pigs transported at normal density displayed signs of stress (elevated heart rates and body temperatures) during the drivers' break. It was proposed that pigs are more capable of adapting to long (550 km) transport conditions when loaded at a density below the present EU requirement.

Pereira et al. (2015) and Garcia (2017) have studied the effects of stocking density on skin temperature and meat quality in pigs transported in Brazil. The stocking densities used were 236, 251, and 275 kg/m². These exceed those permissible in Europe and thus the findings are of little relevance or practical use at this time. However, it was reported that animals transported at 236 and 251 kg/m² did not differ in terms of meat quality problems and difference in the densities did not have any effect on the skin temperature and skin lesions.

> The recommended space allowance of 235 kg m-2 for 100 kg is often questioned in relation to the impact of its application to pigs of other body weights and ages.
>
> The definition of stocking densities or space allowances for pigs in transit should be revisited. The calculations should be based upon pig body weights (allometrics) and take in to account any special requirements for the type of animal or for a procedure (e.g. feeding and watering). The specified space requirements for weaner piglets should be re-examined.

Thermal and Ventilation

Knowles et al. (1998) have defined the ambient temperature below which pigs should not be continuously showered in lairage. The study examined groups of approximately 50 pigs each, showered and un-showered, on 10 days with a range of ambient temperatures. The pigs' behaviour and any damage to their skin were recorded, various measures of body temperature were taken before and after showering, and blood taken at slaughter was analysed for plasma creatine kinase, cortisol and lactate.

Showering prevented the usual reduction in activity observed in pigs in lairage at high ambient temperatures. On the basis of the reduction in their flank temperature during showering it was recommended that pigs should not be showered continuously if the temperature inside or outside the lairage falls below 5°C, and showering should cease if they are seen to be shivering.

Warriss et al. (2006) have compared the effects of fan-assisted and natural ventilation of vehicles on the welfare of pigs being transported to slaughter
The study employed a single vehicle with different ventilation options on specific decks. Summer journeys of 3 hours duration plus one hour holding were studied under UK conditions. Average body weight of transported pigs was 91 kg. The pigs' body temperature was recorded as the temperature of the blood lost at exsanguination, and as the temperature of the inner surface of the ear measured by thermal imaging. The pigs carried on the upper deck were hotter than those carried on the lower deck, and the pigs carried at the front of the vehicle were hotter than those at the back. There were small differences between the temperatures of the pigs in the different pens, but overall the temperatures of the pigs kept in pens with fan-assisted ventilation were no lower than those of the pigs kept in pens with natural ventilation. The higher temperature of the pigs transported in the front of the vehicle was associated with significantly higher serum concentrations of cortisol and activities of creatine kinase, and a tendency to higher albumin concentrations and osmolality, suggesting that they may have been exposed to more physical and psychological stress, and were possibly slightly more dehydrated, than the pigs in the rearmost pens. The type of ventilation had no effect on the blood composition of the pigs. Surprisingly the findings of this study did not indicate any benefits of fan assisted mechanical ventilation although the methodology for monitoring of body temperature was not entirely optimal and the internal vehicle thermal load distributions may have confounded some of the impacts on the animals in different locations and ventilation types. No clear conclusions can be drawn concerning advantages and disadvantages associated with ventilation type.

Barton Gade et al. (2007) have studied the causes of pre-slaughter mortality in Danish slaughter pigs with special emphasis on transport. The study employed annual statistics for transport and lairage mortality and these were used to investigate factors leading to pre-slaughter mortality. The study examined effects of producer, haulier, abattoir and transport distance (< 100, 100–200 and > 200 km) on transport mortality. Overall, transport mortality increased with higher temperature and lower relative humidity/wind speed but a combination of temperature and humidity that fell into the danger zone, as defined by the Livestock Weather Safety Index, almost doubled transport mortality from a level of about 0.016 to 0.031%. Multiple deaths on the same transport journey were also more frequent during the hotter months of the year. Transport mortality increased with increasing transport distance, especially during warmer weather. Producers, hauliers and abattoirs had widely varying transport mortality. Eighty-nine percent of producers, 11% of hauliers and 86% of farmer transport had no mortality at all. Producers and farmer transport supplying less than 1,000 pigs had higher transport mortality than those supplying more pigs, whereas it was independent of supply for hauliers. It was concluded that the study showed that internal environment within the vehicle and transport pattern, including the time the vehicle is stationary, are important factors for mortality and that particular efforts should be made if weather forecasts predict dangerous combinations of temperature and humidity.

Fox et al. (2013) examined the effects of water sprinkling market pigs in a stationary trailer upon behaviour, gastro-intestinal tract temperature and trailer micro-climate. Using ingested temperature capsules the study looked at changes in gastrointestinal temperature of 115 kg fat pigs during and after 2 hour journeys to slaughter in pot-bellied vehicles in Canada at ambient temperatures between 14-26°C. The findings suggest that sprinkling pigs in a stationary vehicle when ambient temperature exceeds 23°C has the potential to prevent increases in body temperature during short duration transport without detrimental effects on ammonia levels or behaviour during unloading.

Kephart et al. (2014) have studied the efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures. The conditions studied were classified as warm (<26.7 °C) and hot (≥26.7 °C). Four sprinkling methods were compared; no sprinkling, sprinkling of pigs only, sprinkling of bedding only and sprinkling of pigs and bedding. In warm weather, there were no differences between sprinkling treatments for surface temperature, vocalisations, or slips and falls. However, stress signs were 2% greater when sprinkling pigs or bedding only, compared to control. In warm and hot weather, sprinkling did not affect non-ambulatory, dead, or total transport losses. Despite no clear indications of the effects of sprinkling strategy being apparent from this study it was asserted that the inference space of this study is relatively small and so further studies should be conducted to see if these results are applicable to other geographical regions and seasons.

Xiong et al. (2015) have determined the characteristics of trailer thermal environment during commercial swine transport managed under U.S. Industry Guidelines. Temperature and thermal conditions of the interior of swine trailers during transport were monitored over a broad range of outdoor conditions (34 trips total) managed according to industry best practice (Transport Quality Assurance (TQA) guidelines (NPB, 2008)). For the outdoor temperature range of 5 °C to 27 °C, generally acceptable trailer thermal conditions were observed according to the TQA (acceptable thermal conditions were observed based on the criteria that no more than 10% of the trip duration was above 35 °C or below 0 °C). Recommended bedding, boarding and water application were sufficient in this range. Beyond this outdoor temperature range, undesirable conditions within the trailer were prevalent. Areas for potential improvement in transport management were identified. Stops resulted in rapid increases in temperature, which could be beneficial during cooler outdoor temperatures, but detrimental for warmer outdoor temperatures.

Harmon et al. (2017) have attempted to evaluate the conditions during weaned pig transport. The study characterised the environmental conditions within typical transport trailers for weaned piglets to determine if current management practices and trailer design provide an acceptable environment as evidenced by mortality rates and environmental parameters. Secondly, ventilation regime was examined by analysis of airflow patterns in a transport trailer using a scale model in a wind tunnel. Data from 78 usable transport journeys were collected for air temperature in each trailer compartment, ambient temperature, distance travelled, time travelled, stocking density, and mortality by compartment. The 78 trips had an average distance of 778 km (range of 264 to 1016 km), travel time of 8.51 hours (range of 3.4 to 12.3 hours), and mortality rate of 0.031% (range of 0 to 1.11%). There was no significant difference in mortality by compartment. The results indicated that if pigs are transported at a higher stocking density, the compartment temperatures would be similar during cold weather (e.g. 2°C). Under mild weather conditions (e.g. 16°C) significant differences could exist in compartment temperature between part of the upper deck and the lower deck. In comparison, no significant differences were found at warm conditions e.g. 29°C. In addition to the weather influence, in-trailer environment is affected by the side openings which may be adjusted by the driver. A 1/7th scale model of a livestock trailer was placed in a wind tunnel to examine flow characteristics within the trailer including velocity by location and direction. Trials were run with and without the front vents covered and with and without compartment partitions in place. The sides remained open for all trials. Centre-line velocities in the compartments varied from 11% to 22% of the wind tunnel speed with trailer averages ranging from 14% to 16%. Pen partitions within the trailer had an impact on centre-line velocity averaging 14.3% to 15.4% of wind tunnel speed, whereas covering the front vents or not had no effect on the centre-line velocities. When the front air vents on the trailer were uncovered, air flow was from the back of the trailer toward the front. When the front air vents were covered, air flow direction was mixed with most of the upper compartments having front to back flow and most of the lower compartments having back to front flow. This study supports further investigation of passive and indeed mechanical ventilation systems for pig transport particularly in hostile thermal conditions and on long journeys.

Transport Practices

Brown et al. (1999) have studied the effects of pre-transport feed withdrawal period upon behaviour in lairage and some aspects of blood chemistry and carcase damage. Pigs were deprived of food for up to one hour, 12 hours or 18 hours before being sent for slaughter. Blood samples were analysed for cortisol, lactate and creatine phosphokinase. The carcases were assessed for skin damage as an index of fighting, and rigor in the hind leg as an indicator of stress and/or fatigue. General activity was very high on entry to the lairage pen. Drinking and mounting occurred almost immediately. Fighting developed after an exploratory period, and could last up to 60 minutes. The period of food deprivation had no effect on average skin damage or rigor score, but the frequency of carcases with the highest scores was different. The pigs deprived of food for up to an hour had the lowest incidence of severe skin damage and high rigor scores. Boars had a higher incidence of severe skin damage but a lower incidence of carcases with a high rigor score than gilts. Liver glycogen was almost completely depleted in the pigs deprived of food for 12 and 18 hours and was lower in the pigs deprived for up to an hour than in animals fed immediately before slaughter. The period of food deprivation had no effect on the levels of cortisol, creatine phosphokinase or lactate in the blood. The study may indicate that short periods of pre-transport food withdrawal (e.g. one hour or less) are better for pig welfare as assessed by physiological or stress responses and carcase characteristics but that might be offset by the risk of pigs will full stomachs experiencing travel sickness.

Bradshaw et al (1996) have compared the behavioural and cortisol response of pigs and sheep during transport. The study revealed that the behaviour of pigs and sheep during short road transport journeys differed markedly. Pigs became very travel sick. It was also noted that pigs re-ingested their vomit within five minutes of the end of a journey (indicating recovery time was rapid) and travel sickness may therefore be overlooked if animals are not unloaded immediately. Pigs spent most of their journey time lying down. The fact that pigs stood more on rough journeys may have been to alleviate the effects of travel sickness. In contrast, sheep did not become travel sick. They tended to stand in both conditions which may make them susceptible to sudden vehicle movement. Since they also walked more and engaged in social interactions (mainly aggressive head butts) on rougher journeys they may be particularly susceptible to bruising. There was little evidence of habituation to journeys, although sheep generally tended to lie down more during later journeys. Cortisol levels were higher for both pigs and sheep on rough journeys compared with smooth journeys and were much higher in both conditions compared with control. This indicated that both pigs and sheep were sensitive to the particular 'roughness' of the journey. While both species are sensitive to the 'roughness' of journeys they show a marked difference in their behavioural response to transport. Pigs are prone to travel sickness and may require space and a substrate in order to lie down, while sheep spend most of their time standing and also walk and socially interact (which may lead to bruising). The study demonstrated the importance of developing welfare guidelines which are species specific.

Lewis and Berry (2006) have examined the effects of season on the behaviour of early-weaned piglets during and immediately following transport. In North America commercial transport of piglets occurs without supplemental heat, over long durations (24 hours) and without feed and water. In this study scan sampling was used to compare behaviour in transported piglets across seasons (summer, autumn and winter) representative durations. The journey durations were 0 (control) 6, 12 or 24 hours. Resting behaviour during transport increased with transport time in frequency from 59.8% (1–12 hours) to 91.5% (13–24 hours). This pattern was more defined in winter and autumn implicating cold as a causal factor. Higher levels of post-transport resting in transported (81.4%) compared to control piglets (77.5%) may suggest fatigue is a causative factor. As the duration of transport increased, post-transport drinking frequency increased, although significance was reached between control (2.4%) and 24 hours of transport (3.7%) only. Long transport durations may thus delay hierarchy development, require additional coping strategies with respect to cold and increase the risk for dehydration. During winter transport the frequency of piglet interactions (three piglets) was much lower than in summer (39 piglets) and fall (18 piglets) indicating that the cold temperatures may have affected establishment of a dominance hierarchy. Higher levels of resting for 3 days in winter and 2 days in summer could indicate more post-transport fatigue in these seasons. Transport, irrespective of season, resulted in behaviour indicative of coping strategies. The study suggests that more attention should be paid to behavioural impacts of long distance transport and thermal environments for piglets. However, in the absence of complementary further research it is not possible to make any clear recommendations based on the outputs of this work alone.

Peeters et al. (2008) have examined the effects of driver and driving style on the stress responses of pigs during a short journey (65 km) in a small trailer. The study was not concerned, primarily, with commercial transport, and was designed as a model study, requiring more research in order for results to be generalised. The study determined the combined effect of driver and driving style on the behaviour, salivary cortisol concentration, and heart-rate variability of pigs during a short journey. In addition, the effect of differing accelerations (longitudinal, lateral, and vertical) of the trailer on these variables was studied. Three different drivers transported the pigs using a normal, a quiet, and a wild driving style (the latter two in relation to their normal style). Driving style mainly had an effect on the longitudinal and lateral accelerations. Salivary cortisol increases were lowest for the wild driving style (probably an outcome of shorter journey durations rather than driving style!). It was proposed that acceleration due to manoeuvring as opposed to acceleration due to overall speed should be avoided. Also, in practice, journeys should take as brief a time as possible. Increasing acceleration saw an increase in the proportion of pigs standing during the journey and a decrease in the proportion of pigs lying down. Measurements of variability in heart rate revealed that lateral acceleration was an important stressor for pigs. It was concluded that, as driving style has an effect on different stress variables, increased driver awareness of the effects of their driving on the responses of pigs, would improve pig welfare.

Driessen et al. (2008) investigated the potential use of olfactory substances in reducing transport stress in pigs. The substances were employed in transport simulation trials and stress was assessed by measurement of heart rate and lying behaviours. Five treatments were tested through the application of each substance to pigs' snouts with a paintbrush. These consisted of: 1) control treatment (wiping without product); 2) 2 ml of a synthetic, maternal-like pheromone; 3) 5 ml of a synthetic, maternal-like pheromone; 4) a commercial, non-relevant odour and 5) 2 ml of a placebo (solvent of the synthetic pheromone without active ingredients).
In total, 90 pigs took part in this study and each treatment was tested on a group of three pigs with six replicates per treatment. Pigs were vibrated in the vertical direction in a transport simulator with a frequency of 8 Hz and an acceleration of

3 ms^{-2}. Cardiac activity and lying behaviour during vibration were quantified. The effect of vibration was found to be statistically significant, i.e. causing an increase in heart rate and numbers of ventricular ectopic beats (VEB). Both 2 and 5 ml of synthetic pheromone were generally found to decrease the minimum, mean, and peak heart rate values in comparison with the other treatments (in particular the control and the non-relevant odour group) but only minimum heart rate reached statistical significance. However, the number of VEBs was highest for these two synthetic pheromone groups during vibration. No dose-dependent synthetic pheromone effects were found and there were no differences in the amount of time pigs spent lying. It was concluded that the use of olfactory substances may support pigs' ability to cope with real transport conditions thereby improving their welfare.

Barton Gade (2008) has addressed the effects of rearing system and mixing at loading on transport and lairage behaviour and meat quality: comparison of outdoor and conventionally raised pigs. Behaviour of pigs was monitored recorded and analysed on journeys lasting 3 to 4 hours journey followed by 2 hours lairage. In addition to behaviour, blood chemistry at slaughter and meat quality characteristics were determined. Non-mixed outdoor pigs settled more quickly during transport and lay down to a greater extent at the end of the journey and lairage period compared with conventionally raised pigs. Mixing led to fewer pigs sitting and lying during transport for conventionally raised pigs, where nearly 80% were still standing at the end of the journey. Outdoor pigs were less aggressive than conventionally raised pigs especially during lairage and had a lower frequency of unacceptable skin damage in the rear and shoulder area. Aggressive interactions were almost exclusively confined to mixed groups and occurred mainly between pigs from different farm pens, i.e. between unfamiliar animals. Mixing at loading led therefore to higher levels of unacceptable skin damage. Mixed, conventionally raised pigs had higher plasma creatine kinase (CK) activities than non-mixed ones (1132 v. 761 U/l, respectively). Outdoor pigs had similar CK activities, irrespective of mixing (682 and 771 U/l for mixed and non-mixed, respectively). In general, the effects of rearing system and mixing on meat quality measurements taken early post mortem or the day after slaughter were slight, but the trends seen support the CK results, and show that conventionally raised pigs may have found mixing pre-slaughter to be more physically stressful than outdoor pigs did. This work suggests that the strategy for mixing pigs should be considered in relation to production system and other factors that might impose transport stress.

Averos et al. (2008) described the factors influencing the mortality of pigs in transit to slaughter in a pan-European study examining 739 journeys to 37 different slaughterhouses. Average mortality was 0.11% and injury rate 0.36%. In 29% of journeys pigs were not fasted prior to transport and the risk of DOA increased in this group by 100%. The risk of mortality increased with temperature and in fasting pigs temperature was amore important risk factor than journey duration. Risk was inversely proportional to loading time and the highest risk was in pigs not fasted and when injuries were recorded.

The same authors (Averos et al. 2010) examined the factors responsible for mortality in weaned piglets in transit and studied 109 journeys in different European countries. In that study it was reported that overall, 0.07 per cent of all the transported piglets were found dead on arrival, and deaths of piglets were recorded in 13.8 per cent of journeys. Modelling of risk factors included the total duration of the journey, the mean outside temperature during the journey, whether the piglets were fasted before transport, whether drinking water was provided, the type of ventilation in the vehicle and the interaction between journey duration and the mean outside temperature. The duration of the journey and the mean outside temperature showed a significant interaction effect, with a gradual increase in the predicted number of dead piglets with increasing journey duration as the outside temperature increased. Providing the piglets with drinking water and having mechanically assisted ventilation (fans) in the vehicle during the journey significantly reduced the number of deaths, as did fasting of the piglets before transport.

Śmiecińska et al. (2011) have reported slaughter value, meat quality, creatine kinase activity and cortisol levels in the blood serum of growing-finishing pigs slaughtered immediately after transport and after a rest period. Pigs were characterised after immediate post transport slaughter or after a 24 hours lairage period. Pre-slaughter resting had a significant effect on those analysed physiological parameters which were found to be good indicators of pre-slaughter stress. Serum creatine kinase activity and cortisol levels were higher in blood samples collected after transport (during carcass bleeding) than in samples collected before transport, pointing to a strong stress response of animals to pre-slaughter treatment. The decrease in serum cortisol levels in blood samples collected during bleeding from the carcasses of pigs slaughtered after a 24 hour rest period, compared with samples collected from animals slaughtered immediately after transport, suggests that rest before slaughter alleviated stress induced by pre-slaughter handling operations. This, of course, does not indicate any welfare advantage as the transport stress is the same but there has been a recovery period. This does not indicate improved practice and does not support any proposals for better practice in terms of animal welfare.

Torrey et al. (2013 a and b) studied the effects of season and location on the vehicle in relation to behaviours of transported pigs and concluded that season and location within vehicles differentially affect pig behaviour before, during, and after long-distance transportation. In terms of transport practices it was emphasised that differences in lighting and temperature between seasons and the inclusion of internal ramps within vehicles may play important roles in the welfare of pigs transported to slaughter.

Martínez-Rodríguez et al. (2014) have examined the physiological responses and blood gas exchange following long-distance transport of piglets weaned at different ages over unpaved or paved roads. Piglets were studies at three ages 10, 15 and 21 days. The journey duration employed was 6 hours. Four blood sampling procedures were performed with all groups 24 hours before weaning while the piglets were at rest inside the piglet boxes and immediately after weaning but before transport. The third sample was collected upon the arrival of each group of piglets at the farm and the final sample was collected 15min after the arrival of each group. The results indicated that the weaning process in piglets alters their acid–base balance by increasing lactate and glucose concentrations regardless of the age at weaning. This hyperlactataemia is accentuated when the animals are transported for 6hours immediately post-weaning at 10 and15 days of age, regardless of the conditions of the roadway used. The effects were the same in 21-day old piglets but only when they were transported on unpaved roads. Road type may exert an important influence on physiological stress imposed upon young piglets in transit and should be considered in journey planning and preparation.

Roldan-Santiago et al. (2014) studied the welfare of recently weaned piglets transported on unpaved roads and examined the effects of age and the use of straw bedding. The study evaluated the physiological responses of piglets weaned at three different ages and transported immediately over unpaved roads with and without the use of straw bedding in the transport vehicle. The piglets were weaned and then transported at 8 days old, 15 days old or 22 days old. All journeys were of 1 hour duration. The piglets in each one of the three groups were divided into two subgroups firstly those transported over unpaved roads with straw bedding and secondly transported over unpaved roads without straw bedding. Blood samples were taken as soon as the piglets arrived at the destination. Blood pH, haematocrit (%), glucose (mg/dL), electrolytes (Na^+, K^+ and $Ca^{2+)}$ (mmol/L)), lactate levels (mg/dL), partial pressures of carbon dioxide (pCO_2) and oxygen ((pO_2) (mm Hg)), bicarbonate (HCO3 $^-$), and total carbon dioxide (TCO_2) were determined. Piglets that were weaned at 8 and 15 days of age and then transported without straw bedding were found to be more susceptible to metabolic, acid–base, hydric, and gas exchange imbalances. Blood concentrations of pO_2, Na^+, K^+, Ca^{2+} and pH were not affected by transport in piglets weaned at 22 days of age in vehicles using straw bedding. It was concluded that regardless of age and trip conditions, the transport of recently weaned piglets constitutes a stressful situation. Even 1 hour of transport time was sufficient to cause imbalances in their physiological blood indicators. It is proposed that the work supports the use of adequate bedding for transport of young pigs and that road type should be considered in journey planning.

The same authors (Roldan-Santiago et al., 2015) have considered the physio-metabolic responses to road transport in weaned piglets for a short period and the effects of straw bedding. Piglets were weaned and transported at the following ages: 8, 15 and 22 days. The duration of each journey was 1 hour. The piglets in each group were further divided into two those transported with or without straw bedding. In order to assess their responses to weaning- and transport-induced stress, the study evaluated a thorough physio-metabolic blood profile. The 8- and 15-day old piglets transported without straw bedding showed increases in their pCO_2, blood glucose, blood lactate levels and the percentage of haematocrit, but a decrease of pO_2 upon arrival. In contrast, the 22-day old piglets transported on the same road with straw bedding were able to re-establish their blood concentrations of lactate, pCO_2, pO_2, Na^+, K^+, Ca^{2+} and pH during the trip. The study indicates the important of provision of appropriate bedding for the transportation of newly weaned piglets.

van Staaveren et al. (2015) have characterised the effects of mixing entire male pigs prior to transport to slaughter on behaviour, welfare and carcass lesions. Mixing entire males stimulated mounting and aggressive behaviour but did not influence carcass lesion scores. Carcass skin/tail lesions scores were correlated with scores recorded on farm ($r_{skin} = 0.21$ and $r_{tail} = 0.18$, $p < 0.01$) suggesting that information recorded at meat inspection could be used as indicators of pig welfare on farm.

Herskin et al. (2017) have studied the specific issue of holding of pigs (cull sows) in a transfer vehicle prior to collection on a commercial truck for transport to slaughter. This practice is necessitated by biosecurity requirements limiting access of commercial vehicles to farm premises. In this study sows were held in the transfer vehicles for periods between 6–59 min. In this period, the behaviour of the sows was characterised by aggression and only very limited resting. These preliminary results suggest that a pre-transport stay in a transfer vehicle can be challenging for sow welfare, especially for longer stays and during hot days.

The biggest risk factors for mortality during transport are temperature, not fasting prior to transport and rapid loading speed. Mixing pigs at loading, particularly of conventionally reared pigs, leads to more aggression and less lying during transport. Outdoor pigs are less aggressive than indoor reared pigs, and had lower incidence of damaging skin lesions from fighting.

Other and general issues

The factors affecting the mortality of pigs being transported to slaughter have been analysed by Averós et al. (2008). The study examined commercial pigs in 5 EU Member States and analysed 739 journeys to 37 different slaughterhouses. A multilevel logistic regression model was used to identify and quantify the effects of factors affecting the mortality of pigs in transit. Information was assembled that related to the welfare and mortality of the pigs and the number of injuries observed. The factors investigated included the average temperature during the journey, its duration, the average loading time per pig, the recorded injuries, fasting before transport, and the interaction between fasting and journey duration were used in the final model. The study indicated that the average mortality was 0·11 % and the average proportion of injured pigs was 0·36 %, and these figures were significantly correlated. In 29 % of the journeys the pigs were not fasted before being loaded, which doubled the risk of mortality irrespective of whether the pigs were injured or not. The risk of mortality increased with average temperature. In journeys with fasted pigs that did not have any recorded injury, average temperature was more important than the duration of the journey. The risk of mortality increased as the average time taken to load them decreased, and the risk was highest when the pigs were not fasted and when injuries were recorded. Other factors such as the country, loading density, availability of drinking water and type of ventilation did not affect the risk of mortality.

Voslářová et al. (2010) undertook a survey trial examining the impacts of housing system and the numbers of transported animals on transport-induced mortality (DOA) in slaughter pigs in the Czech Republic over a 4 year period. The lowest mortality rate during subsequent transport to slaughter houses was detected among pigs fattened on solid floor (0.047%) and on deep bedding (0.084%). The highest mortality during transport was detected among pigs fattened on fully or partially slatted floor (0.139%), a significant difference was found compared to other housing types. Assessment of the influence of individual pig load size on mortality showed the lowest mortality among pigs transported in loads of up to 40 animals (0.053%). Mortality during the transport in loads of the size of 41 to 120 animals was 0.130%, and for loads of the size over 120 pigs the mortality rate was 0.156%. Those mortality rates were significantly higher compared to the load sizes of up to 40 animals. Clearly production system and load size have important effects upon pig welfare and stress during transportation.

Based upon behaviour and meat quality measures Dalla Costa et al. (2016) have suggested that it may be preferable to initiate feed withdrawal on farm (up to 18 hours) before transport rather than in lairage.

Zurbrigg et al. (2017) have reviewed pig-level risk factors for in-transit losses in swine. It was proposed that in-transit losses (ITL) are not fully explained by the most commonly cited risk factors, such as environmental temperature, stocking density and journey length, and that other risk factors must be considered. Low numbers of ITL compared with the large number of pigs shipped each year imply that individual pig factors should be given greater consideration. Pig health pertaining to ITL is not well studied and post mortems are rarely completed on ITL pigs. In particular, compromised cardiac function combined with a limited ability for cardiac compensation may predispose pigs to ITL as a result of the exertion experienced during sorting, loading, and transport. Varying stages of cardiac compromise could explain the variable nature of ITL. Future research should focus on investigating the health conditions which could make a pig more susceptible to death or becoming non-ambulatory during transport.

Welfare and stress measures and outcomes

von Borell and Schaffer (2005) have reviewed the legal requirements and assessment of stress and welfare during transportation and pre-slaughter handling of pigs. The clear and novel recommendation was that apart from methodological solutions for measuring stress and welfare, the appropriate handling of farm animals during transportation and the pre-slaughter period should be monitored as part of a quality assurance scheme. The authors recommended a clear approach based on the Hazard Analysis of Critical Control Point (HACCP) concept. The review identifies a number of specific critical control points for pre-slaughter handling and transport of pigs and these should be integrated in to new guides for the future.

Pineiro et al. (2007) have characterised the acute phase protein (APP) responses to prolonged transportation in pigs (boars) under commercial conditions. The responses were more pronounced in pigs transported for 24 hours in poorer conditions that those transported or 48 hours in better conditions. In a follow up study, pigs were transported for 12 hours and sampled either on arrival at the slaughterhouse or after 6 hours lairage. Significant increases in major acute phase protein (Pig-MAP), haptoglobin, serum amyloid A, C-reactive protein, and a decrease in apolipoprotein A-I, were observed at slaughter. It may be suggested that transport stress and its extent may be determined by measurement of specific APP responses in pigs.

Averos et al. (2007) studied responses in serum stress parameters in pigs transported to slaughter under commercial conditions in different seasons. Two journey times were compared, 1 hour and 13 hours, under winter and summer conditions. Cortisol, glucose, creatine phosphokinase (CPK), lactate dehydrogenase (LDH), albumin and total protein serum concentrations were measured. All the variables increased during transport and decreased during lairage. Genetics modulated the effect of the rest of influencing factors, with heterozygous (Nn) individuals showing a rougher reaction in short and winter conditions, but with lower dehydration levels. It was suggested that under Mediterranean commercial conditions, stress in transported slaughter pigs was largely determined by season and genetics, so that an adaptation of handling procedures to these seasonal variations is crucial if transport stress is to be reduced. In this and other older studies the stress sensitivity associated with the halothane gene in commercial pigs is an important factor in determining the outcome and impact of transport of pigs. As this mutation responsible for high stress sensitivity has now been eliminated largely that component of this and other similar work has little relevance to today's practice and future policy and strategy.

Salamano et al. (2008) have examined the use of acute phase proteins (APPs) to assess transport stress in pigs. In this study changes in haptoglobin, C-reactive protein and pig-MAP (pig major acute phase protein) were measured after long distance (48 hours) commercial transport in 4 month old pigs (gilts). Blood samples were collected immediately upon arrival in Italy and again later at 14 and 28 days post-transport. Elevations in the APPs were sustained post-transport but were returning to control levels by 28 days. It was proposed that APPs may be useful indicators of welfare during transport and routine management.

Olayinka et al. (2011) studied the effect of ascorbic acid administration on erythrocyte osmotic fragility of pigs transported by road during the hot-dry season. EDTA blood samples collected a day before (pre-transportation), immediately after 8 hours transportation and 7 days post-transportation and erythrocyte osmotic fragility was determined. The ambient temperature and relative humidity measured within the vehicle ranged between 30–39°C and 40–70% respectively. These conditions were deemed to constitute thermal stress. It was suggested that the results of the study indicated that 8 hours road transportation during the hot-dry season could induce stress resulting in haemolysis of erythrocytes and Ascorbic Acid administration ameliorated the stress.

Garcia-Celdran et al. (2012) have investigated the effects of lairage time (3 or 12 hours) on a number of stress markers after 20 minutes road transport. Measures included acute phase proteins (CRP / C reactive protein and Haptoglobin) and N:L ratio (neutrophil:lymphocyte). Consistent with other studies the data indicate that longer lairage allows longer and greater recovery. The value in relation to overall welfare is not clear. The measures employed are proposed as useful stress markers for other transportation studies.

Guardia et al. (2012) have examined circulating biomarkers in pigs transported to slaughter at 5 Spanish abattoirs in 2 seasons. The measures included blood cortisol, lactate concentrations and creatine phosphokinase (CPK) activity at exsanguination.

The relationship between blood parameters, carcase skin damage and pork quality traits was also assessed. The season influenced blood cortisol, lactate and CPK values. Females always showed higher concentrations of cortisol, lactate, and CPK than males. The cortisol concentration decreased in lean pigs that were slaughtered in winter after short lairage periods. The lactate concentration decreased with loading time and increased in summer with lairage time and carcase weight. The CPK activity increased with lairage time, carcase weight, and carcase lean content, and with the duration of winter transport. Lairage time is the most influential pre-slaughter handling practice on the assessed welfare indicators. Blood cortisol, lactate, and CPK activity increased concomitantly with skin damage score.

Soler et al. (2013) have investigated the use of serum amyloid A and haptoglobin determination in saliva as stress markers in swine during transportation. Pigs were subjected to short road transport for 5 hours under winter conditions. Salivary levels of cortisol and serum amyloid A levels were significantly increased following transportation. Serum amyloid A levels were significantly elevated compared to control on arrival at the slaughterhouse and were maximal at 30 and 60 minutes in lairage. Cortisol levels were only significantly elevated on arrival at the slaughterhouse. These results indicate that salivary serum amyloid A but not haptoglobin determination may be a useful biomarker for the assessment of complex stress in pigs, and that it has a more prolonged response than cortisol.

Roldan-Santiago et al. (2013) have reported the use of a range of biomarkers to assess stress and welfare in barrows (male pigs castrated before puberty) exposed to different lairage times without food.

Increasing duration of lairage and food deprivation lairage induced significant reduction in blood pH, accumulation of lactic acid and percentage of haematocrit, amongst other physiological responses. It was concluded that lairage periods longer than 4 hours cause hyperglycaemia, hypercalcaemia, hyperlactataemia, hyper-kalaemia, hyponatraemia, acidosis, and more severe dehydration in barrows.

Seshoka et al. (2013) used Point-of-care (POC) devices to measure plasma metabolic substrates in pigs subjected to stressful conditions. Salivary cortisol, plasma glucose, triglycerides and lactate concentrations were determined before and after transportation to the abattoir and carcass temperature, pH and drip loss were measured after slaughter. The POC devices measured differences in lactate concentrations in pigs transported over different durations and relationships between the lactate and the carcass pH, carcass temperature and drip loss were demonstrated.

Tang et al. (2013) examined the effects of transport journey time on heat shock protein (Hsp) expression and meat quality in pigs. Long journeys were associated with increased serum creatine kinase (CK) activity. The changes in this indicator of muscle damage and fatigue correlated with increased Hsp70 and decreased Hsp90 expression levels in skeletal muscle. Reduced Hsp levels were associated with higher meat quality and a good welfare of the transported pigs. It was reported that the Hsp stress response declined over time in response to the same stress, such as a 6 hour transport stress.

Brandt et al. (2015) have investigated the relationship between physiological markers or indicators post-mortem measures and overall pig welfare assessment from farm to slaughter. Blood temperature was obtained at exsanguination and plasma concentrations of glucose, lactate, albumin and total protein were determined along with creatine kinase activity. All welfare measures were categorised on a three-point and aggregated into an Animal Welfare Index (AWI) using a weighted linear sum of prevalence on animal level. An overall AWI and an AWI per stage were calculated. For AWI at unloading, significant relationships with the plasma concentration of glucose (positive), creatine kinase activity (positive) and total protein (negative) content of the blood were found. It was suggested that one method to identify AWIs above or below a certain threshold might be using the post-mortem measures such as and lactate.

Jama et al. (2016) have employed cortisol and creatine kinase (CK) levels as indicators of transport stress in pigs and have examined correlations with meat quality measures. Cortisol concentrations from saliva, serum and urine were determined and serum creatine kinase activity was measured. There was a significant interaction of sex and time to slaughter on serum cortisol concentration. Gilts had higher CK activities than boars. There were correlations among baseline concentrations of cortisol in the three bio-fluids and meat quality parameters. Time to slaughter influenced the levels of cortisol in saliva and urine, serum CK activity and pork quality differentially in boars and gilts.

Brandt et al. (2017) have proposed a potential model of an animal welfare index for finishing pigs from farm to slaughter based on the Welfare Quality ® principles. Expert opinion may be used to assign weights for welfare measurements as well as stage weights, based on which an animal welfare index within stages (AWI-Stage) as well as across stages (AWI-Overall) was calculated. The underlying complexity of the AWI means that especially the AWI-Stage, after further validation using larger data sets, might be used to compare the level of welfare between herds, vehicles and abattoirs within stages, and potentially function as a feedback mechanism for optimization of the welfare of the pigs or as part of marketing.

Carroll et al. (2018) have investigated the use of haptoglobin, C-reactive protein and hair cortisol as physiological measures of lifetime welfare status of pigs at the time of slaughter. The study examined a total of 66 pigs were used and the serum concentrations of haptoglobin (Hp) and C-reactive protein (CRP) and hair concentrations of cortisol measured at slaughter were assessed in relation to welfare related indicators recorded from the animal during its lifetime Receiver Operator Curve (ROC) analysis was also carried out to get a better understanding of the usefulness of the physiological measures in discriminating animals that had had welfare-related issues recorded during their lifetime from those that had not. Hair cortisol was determined as having ‘moderate’ accuracy in discriminating pigs that were tail bitten on-farm from unbitten pigs while Hp and CRP were determined to have no meaningful discriminatory ability. It was concluded that at this time only hair cortisol measured at slaughter could provide insight into the welfare status of pigs during their lifetime.

Studies have employed growth hormones and factors to assess transport stress e.g. IGF-I and -II and IGFBPs. Measurements of acute phase protein (APP) responses to prolonged transportation are proposed as useful biomarkers e.g. Pig-MAP, haptoglobin, serum amyloid A, C-reactive protein, and apolipoprotein A-I. Some studies recommend the measurement of heat shock proteins (Hsp). More traditional markers have also been employed including cortisol, glucose, creatine phosphokinase (CPK), lactate dehydrogenase (LDH), albumin and total protein serum concentrations.

SHEEP

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). 'Good practices for animal transport in the EU: Sheep ' (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have identified the main areas of welfare concern for the transport of sheep. These have been addressed through identification and integration of recommendations for good and best practice from scientific knowledge, scientific literature, experiences and information from stakeholders. For sheep, as for all other livestock, transportation involves several potential stressors that can negatively affect animal welfare. The new and unfamiliar environment, movement restrictions due to confinement, vibrations, sudden and unusual noises, fitness of livestock, mixing with other animals, temperature and humidity variations together with inadequate ventilation and often feed and water restrictions all have an impact on the animals' state. The effects of all these factors are influenced by the experience and condition of the animals, the nature of the journey, and the duration of transport.

Long journeys have been identified as being potentially more detrimental to the general welfare status of the animals, because of the longer duration of exposure to the stressors mentioned above. Therefore, it is clear that stressful journeys including hostile transport environments or conditions may influence animal health and welfare negatively. Inappropriate handling and transport can be associated with overt injuries, physiological and psychological stress, immunosuppression and metabolic disturbances. These responses may impact upon productivity and profitability through changes in animal liveweight, hydration state and meat quality in slaughter animals. In order that animal welfare can be kept at a high level during transport, it is important that all of those involved in the transport and related operations are properly informed about the animals and how to assess their welfare. Checking the animals before loading will reduce the risk of sending animals for transport that may not survive the journey, or suffer serious welfare consequences. Careful planning of journeys and ensuring the suitability of appropriate vehicles is important, with emphasis placed on compartments height and the use of partitions. Space allowances should be sufficient for sheep taking into account body weight and the presence of wool and thickness of fleece. Long journeys, should be avoided wherever possible and much better conditions are needed if journeys are long. Vehicles should be driven carefully and sudden turns and braking should be avoided, especially on roads with sharp bends or at right angle turns into other roads. Thermal conditions and ventilation management are important to reduce the effects of heat stress on sheep.

The transportation of sheep will now be considered under the headings identified above and derived from the structure of EC 1/2005 and associated annexes.

Journey times – Rest Stops

Broom et al (1996) have reported the physiological effects of a 15 hour journey upon jugular catheterised lambs (40 kg body weight) and compared the responses to those induced by handling, loading and penning but with no transportation. Measurements of plasma concentrations of cortisol, prolactin, creatine phosphokinase and lactase dehydrogenase isozymes, plasma osmolality, haematocrit and body weight were made. Loading and the start of driving produced large increases in cortisol and prolactin concentrations. Plasma osmolality and haematocrit decreased. The major changes in hormone release occurred in the first 3 hour period while, during the remaining 12 hours, the stimulatory effect of transport was present but small. Body weight loss was similar under both stationary and driven conditions. Methodological difficulties with this study mean that clear conclusions regarding the relative contributions to transport stress by travelling and loading and handling cannot be drawn.

Increasing journey times or durations may be associated with increased physiological stress in sheep. Thus as journey length is increased, exertion and potentially fatigue during transport may result from long periods of standing rather than lying down, requiring muscular tension to balance the body during vehicle motion (Terlouw et al., 2008). Physiological effects of increasing transport duration by road (where feed and water are withheld) include increased live weight loss, in older lambs (Sarozkan et al., 2009a, 2009b) and in suckling lambs (Tadich et al., 2009). Sariozkan et al. (2009a) determined weight losses in yearling lambs transported for 5, 10 and 24 hours. Transported lambs were loaded on a lorry at a space allowance of 0.35 m^2/head, while control group (15 lambs) were kept with the same density in the home barn. After each journey, a slight but not significant live weight loss was observed in the transported lambs compared to lambs in control group. Few useful conclusions regarding animal welfare can be drawn from these findings.

Sariozkan et al (2009b) have studied the effects of transport for up to 19 hours upon lambs. Yearling lambs were transported for periods of 3, 6, 9 and 19 hours and measures compared to an un-transported control group. Transported lambs were loaded on the lorry at a space allowance of 0.35 m^2/head while the control group (un-transported) was kept at the same density on the farm. The lambs transported for 3, 6 and 9 hours lost more live weight than the lambs in control group. Compared to the control group, significant increases were determined in the percentage of the liveweight losses in transported lambs with the increasing journey duration. It was recommended that if it is necessary to transport lambs for long journey durations the animals should be rested for feeding and watering during transportation. No specific recommendations are made for journey time limits from this study but it appears that journeys of 9 hours or less may have lower stress and welfare impacts.

In older lambs, most of the reduction in weight during transport was attributed to loss of gut fill which is recovered after feeding upon arrival (Fisher et al., 2010). The findings of Fisher et al. (2010) indicate that healthy adult sheep, transported under favourable conditions, can tolerate road transport durations of up to 48 hours. It is difficult to find data to support prescribed maximum journey times, applicable to all transport types and conditions and more emphasis should be placed on the quality of the journey rather than focusing exclusively on duration.

Stress related to journey duration and space allowance has been investigated by de la Fuente et al. (2012). Two journey durations, short (40 minutes) and long (4.8 hours) were considered at three space allowances of 0.12, 0.20 and 0.25 m^2 per lamb. Lamb behaviour was recorded continuously during the journeys and heart rate was monitored and blood samples obtained pre and post transport for determination of stress biomarkers. Meat quality measures were also made. Lambs stood for most of the time on both long and short journeys. However, the number of lambs undertaking each of the monitored behaviours was found to differ with journey time and space allowance. Heartrate increased with loading and transport. Cortisol, LDH, glucose, albumin and osmolality were higher in suckling lambs transported for a short time than for those transported for longer periods. Space allowance did not affect any of the blood parameters. It was proposed that the study indicated that that short journeys induced higher stress responses in suckling lambs than long journeys. These observations may be attributable to the impact of loading and initial transport novelty and the time required for adaptation and stabilisation.

Dalmau et al. (2014) examined the effects of journey time (1 hour versus 24 hours) on physiological responses and meat quality measures in lambs. The effect of transport on serum biochemistry variables (cortisol, aspartate transaminase, lactate dehydrogenase, blood urea nitrogen, creatine kinase, creatinine and total proteins), salivary cortisol, metabolites of cortisol in faeces, intra-ruminal temperature and meat quality (pH, conductivity, expressible juice, colour and shear force) were assessed. The duration of transport did not affect serum and salivary cortisol concentration however lambs exposed to 24 hours transport had a higher concentration of faecal cortisol metabolites than did those transported for 1 hour. Blood variables were not affected generally by transport. Although no signs of dehydration were found, intra-ruminal loggers showed that animals did not drink during the transportation in the way they did before transport. It was reported that although there is little effect on meat quality, signs of stress are detectable in lambs transported for 24 hours. Therefore, in the case of lambs, the effect of long transportation periods must be considered more in terms of animal welfare than in terms of product quality.

Krawczel et al. (2007) have considered road transportation of lambs for a 22 hour journey, either as a single continuous stage, or as three stages, with rest periods between each stage. The first rest period was 6 hours and the second was 24 hours. Although the lambs receiving rest stops maintained bodyweight and showed little physiological evidence of food deprivation as compared to the continuous journey group, there were no positive impacts on immunosuppression and stress, as measured by cortisol levels. Researchers in Spain have been investigating the sheep welfare and meat quality impacts of interrupted journeys, incorporating stopovers of varying durations at a classification centre (Miranda-de la Lama et al., 2009, 2012a, 2012b). However, they have found a strong interaction with season and climatic conditions.

The impacts of unloading of sheep at control posts upon stress and behaviour has been studied by Messori et al. (2015). The trials involved the characterisation of stress biomarkers and behaviours of ewes during an 8 hour following a 29 hour journey. After the 8 hour rest stop the sheep were transported for a further 6 hours to their destination. One group of sheep was unloaded and housed in a pen (P) at the control post while the other was left inside the truck (T). A third group (C) stayed at the farm as control. During the stop, standing, resting, moving and eating behaviour of all groups was recorded. Blood parameters, salivary and faecal cortisol were assessed at different stages. The behaviour of P animals during the resting period was more similar to C than to the T group, where feeding and lying behaviours were restricted by the limited space allowance. It was concluded that for short resting periods e.g. 8 hours there are no clear advantages in avoiding unloading and loading of the animals in the control post after long journeys.

The effects of rest stop duration on sheep welfare on long journeys have been investigated by Messori et al. (2017). Sheep were transported for 29 hours followed by rest stops at a control post of 8, 16 or 24 hours and then a final transport phase of 6 hours. Measures in each group were compared to un-transported controls. Blood and saliva were collected to assess dehydration, muscular damage, and adrenocortical stress before departure, after each transport-rest stop treatment.

Transport (long distance) affected the hydration of all transported groups but basal values were restored after the short, regardless of the stop duration. No differences in stress level were observed. It is suggested that the welfare of the ewes was not impaired by a stop reduction from 24 hours to 16 hours.

Silva et al. (2017) studied the effects of journey times in lambs. Measures of physiological stress biomarkers, behaviour and meat quality were analysed in relation to journey durations of 1 hour 45 minutes, 3 hours 53 minutes, 7 hours 30 minutes and 10 hours 30 minutes under Brazilian conditions. The lambs were slaughtered 15 hours after arrival. The number of potentially traumatic events observed on these journeys was low for any transport duration. The adrenaline and cortisol concentrations, as well as metabolites that are controlled by them, did not indicate that longer transport was more stressful. However, the carcass mass decreased and creatine kinase concentrations increased linearly with longer transport periods, which may suggest a decrease in welfare. The meat quality of lambs was not influenced by the transport duration.

Healthy adult sheep, transported under good conditions, can tolerate transport durations and associated feed and water withdrawal periods of up to 48 hours without undue compromise to their welfare. For short resting periods e.g. 8 hours there are no clear advantages in avoiding unloading and loading of the animals in the control post after long journeys. If sheep consume large quantities of feed (e.g. in lairage at a control post) after a period without access to feed and water during transportation then the animals must be allowed sufficient time to drink before a subsequent journey is undertaken.

Long Journeys

Recently the effects of long distance transport on lambs have been examined by Miranda de la Lama et al. (2018). 7 month old lambs were transport for 20 hours in Mexico under winter conditions on a pot-bellied truck. The measurements made included deep body temperature and a number of stress and metabolic biomarkers e.g. plasma cortisol, glucose and creatine kinase (CK), and neutrophil/lymphocyte ratio as well as meat quality parameters. Location on the truck affected the stress responses exhibited by the lambs. The authors propose a link between thermal stress during transport, elevated physiological indicators of stress and poorer meat quality.

Feeding and Watering Intervals

Jackson et al. (1999) studied the effects of 24 hours of water deprivation at different temperatures and at appropriate stocking densities upon the blood chemistry and behaviour of sheep to simulate conditions encountered in transportation. The animals were placed in chambers kept at either l4°C or 21°C. Within each chamber, half the sheep had access to water but they were all kept at a space allowance of 0.41m^2 per animal without feed. After 24 hours they were returned to their individual pens and offered hay and water. Behaviour and a range of biochemical measurements of dehydration and feed restriction were recorded before, during and after the treatment period. There was no evidence of dehydration, and sheep with access to water drank less than they did before the treatment. The plasma concentration of free fatty acids increased during fasting and, post-treatment the intake of hay was greater than before treatment. The rapid post-treatment intake of dry feed was associated with some evidence of dehydration, as indicated by increased plasma osmolality and plasma vasopressin concentration. It was suggested that following provision and consumption of large quantities of feed after a period without access to feed and water during transportation sheep must be allowed sufficient time to drink before a subsequent journey is undertaken.

Cockram et al. (2000) investigated the effects of post-transport novel environments on recovery from transport after a 16 hour journey. There was no obvious effect of a novel post-transport environment on blood biochemistry. The observed post-transport reductions in feed and water intakes in a novel environment did not impact upon the ability of the sheep to recover from the feed and water deprivation associated with transport.

For most animals current transport practice includes the withdrawal of feed and water prior to transportation. For sheep the removal of water prior to transport poses little welfare risk, as long as the climatic conditions and overall deprivation period do not result in dehydration (Fisher et al., 2009). Without the additional stress of transport, sheep can be deprived of water for up to 72 hours in mild conditions (Cole, 1995, 2000), however, when high temperatures prevail, dehydration can occur rapidly (Lowe et al., 2002). Short term feed deprivation (up to 34 hours) has little effect on blood glucose, meat quality and yield (Fisher et al., 2015), although the welfare effects of subjective experiences such as hunger are unknown.

For long journeys by sea (vide infra) a key factor is the successful familiarisation of the animals and their adaptation to the feed / diets that will be supplied in transit. It is recognised that inanition is one of the predominant contributors to mortality in sheep undergoing sea transport (Richards et al., 1989). However, under commercial conditions, sheep commonly spend 5 days in the assembly centre (Phillips and Santurtun, 2013). Little recent research has explored potential aids to feed acclimation since the work investigating the effects of feed type, virginiamycin and dexamethasone on feed acceptance and intake carried out in the early 1990s (Adams and Sanders, 1992; Bailey and Fortune, 1992; McDonald et al., 1994; Norris et al., 1992).

Given the risk of dehydration, water deprivation is considered to be a more significant risk to welfare than food deprivation. Krawczel et al. (2007) studied water deprivation in continuously transported lambs. Results did not indicate that the lambs were dehydrated at the conclusion of 22 hours transport and they were reluctant to drink when offered water on the trailer after 14 hours transportation. However, the effect of water deprivation on suckling lambs could be different from that described in older lambs and sheep, even for short journeys. De la Fuente et al. (2010) showed that suckling lambs show symptoms of dehydration when transport times are increased from 30 minutes to 5 hours. In contrast, when feed is withdrawn, research suggests that healthy, un-transported sheep can tolerate long periods (2–3 days) without food before undue compromise to their welfare (Cole, 1995). During sea transport, feed and water are provided (usually ad libitum); however, inanition can occur in sheep that fail to adapt to the shipboard ration (Phillips and Sunturtun, 2013). Inanition is common in over-fat sheep, which have depressed appetites (Higgs et al., 1991). The Australian Standards for the Export of Livestock ASEL addresses the issue of inappetance in sheep, and it contains requirements for a feed transition period, monitoring and management of affected livestock (Schipp, 2013). Inappetance and inanition in sheep during live export remain a key problem, and research is required to further identify the factors that predispose certain sheep to this condition and develop mitigation strategies.

Fisher et al (2015) have characterised the effects of food withdrawal in sheep prior to a one hour journey by road to slaughter. Cull ewes were held off pasture for 0, 9, 18 or 30 hours prior to the journey. They were held in lairage for 3 hours before slaughter. The serum concentrations of metabolites indicative of adaptation to fasting were determined. In addition, several attributes of carcass quality were measured. The results suggest that sheep in variable body condition adapted to the periods of feed deprivation by mobilising their energy reserves without any evidence of metabolic depletion (e.g. depleted blood glucose or high meat pH). However, being deprived of feed they probably experience a degree of hunger.

> Slaughter lambs or adult sheep can tolerate withdrawal of water for up to 22 hours at cool temperatures, without showing an increase in drinking when water is provided. However, suckling lambs are more sensitive to dehydration after only 5 hours. Healthy adult sheep can cope with food deprivation for 2-3 days by mobilizing body reserves, and withdrawal of animals from pasture up to 30 hours before transport can occur without metabolic depletion, although the animals may experience the adverse consequences of hunger.

Handling, Loading and Unloading

Handling, loading and unloading are generally recognised as potentially stressful to sheep. These procedures induce physiological stress responses in sheep (Broom et al.,1996; Parrott et al., 1998a, 1998b). Parrott et al (1998) examined stress hormone and heart rate responses of sheep to transportation (3.25 hours) following two different loading procedure. The animals were loaded onto a transport vehicle using either a conventional tailgate ramp or a crate raised with a hydraulic lift. Measurements were made of plasma concentrations of cortisol, prolactin and catecholamines (adrenaline and noradrenaline). Heart rate increased during loading, regardless of the method used. No changes in the concentrations of cortisol or catecholamines were detected, although a small increase in prolactin was noted when animals were loaded using the ramp. During transport, all sheep exhibited increases in plasma cortisol concentrations which were greatest during the first 2 hours of the journey. It was concluded that the effects of the two loading procedures were similar and that transport appeared to be more stressful than loading.

Studies of the impacts of transport on the stress responses in sheep have shown that loading and the initial transport phase caused a significant increase in plasma cortisol and lactate dehydrogenase which diminished over the course of the transport period (De la Fuente et al., 2010). This supported the work of Cockram (2007), who showed that plasma cortisol concentration declined within a few hours and was often near to, or at, pre-transport values by the end of a 24 hour journey. The main problems with handling of sheep arise from inadequate facilities and the naivety of the animals to handling (Burnard et al., 2015). Handler experience and attitude are key to ensuring ease of handling Hemsworth (2007), Hemsworth and Barnett (2001) and Hemsworth et al. (2011). There is little new research examining strategies to improve transport loading and unloading practices for sheep.

Loading and initial transport of sheep causes the greatest change in stress responses, compared to later in the journey. Handler experience and attitude, suitability of handling facility design and familiarity of the animals with handling can all improve the experience for sheep.

Means of Transport

Hall et al. (1998) studied 15 hour journeys for sheep and analysed the effects of vehicle motion, stocking density and sound level upon the animals by a number of stress biomarkers. It was concluded that vehicle motion can impose significant stress upon the sheep particularly at low stocking density where postural stability may be an issue.

The study did not reveal any significant stress or discomfort associated with sound level or intensity.

Ruiz-de-la-Torre et al (2001) examined the effects of vehicle movements on the stress response of slaughter sheep. Lambs were transported for 15 hours on different road types. Animals in each group were monitored for heart rate and the plasma levels of cortisol, creatine kinase and lactate dehydrogenase, before the journey began, after 4, 8 and 12 hours and at slaughter. The behaviour of the lambs was recorded in transit. The pH of the meat was measured 45 minutes and 24 hours post-mortem and its colour was assessed 24 hours post-mortem. The lambs transported on smooth roads had a lower heart rate and lower plasma cortisol concentrations after 8 and 12 hours than the lambs transported on rougher roads. Twenty-four hours after slaughter the pH of the meat of the lambs transported on smooth roads was lower than that of the lambs transported on rougher roads. It is proposed that the high degree of vibration associated with transportation on rough road surfaces constitutes a more stressful journey experience for the lambs. Unfortunately as the study does not include characterisation of the vibration and acceleration regimes on each road type it is not possible to use the outputs of the study quantitatively to define acceptable or unacceptable vibration / acceleration environments in transit.

Rodriguez et al. (2017) studied the effects of bedding material on some welfare indicators in lambs during transportation over 334km to slaughter in Spain under winter conditions. Three bedding materials, sawdust, rice husk and a double layer of sawdust used during transportation to the slaughterhouse were compared. Physiological indicators (glucose, lactate, creatinine, lactate dehydrogenase, creatine kinase, cortisol and catecholamine) were sampled before and immediately after the transportation. Bedding material during transport did not affect any of the physiological indicators analysed, except for creatinine, which was lower in lambs transported with rice husk. It was conclude that all substrates tested could be recommended as bedding material during transport, without showing significant differences on animal-welfare indicators or carcass microbiological quality.

Space Allowance / Stocking Density

The World Organisation for Animal Health (OIE) Terrestrial Animal Health Code (OIE, 2015) recommends that the space provided on a vehicle or in a container (during land transport) is determined by the need for livestock to lie down or to stand during the transit process. Cockram et al. (2004) found that sheep spend most of a 7 hour journey standing rather than lying down, but the amount of lying behaviour increases with journey duration. High stocking density does not allow animals to lie down (Knowles et al., 1995), but when animals travel at low stocking density, they can lie down and move, but their welfare may still be at risk if driving techniques are poor. The majority of recommendations for space allowance provided to adult sheep in transport are defined according to weight ranges.

Cockram et al. (1996a, 1996b) identified that space allowances that make it possible for sheep to lie down in transit should be approximately 0.25–0.27 m^2 per sheep of 35 kg live weight. De la Fuente et al. (2010) indicated that for lambs of 12–14 kg live weight, on journey times <5 hours, reducing space allowance to 0.12 m^2/lamb did not affect physiological responses or meat quality, as compared to the EU minimum space requirement per head of 0.20 m^2 for lambs over 26 kg live weight. Similarly, Cozar et al. (2016) indicated that there were no significant differences in physiological indicators in lambs of approximately 28 kg live weight, transported at a range of space allowances between 0.16 and 0.30 m^2. For sheep, it is therefore recommended that space allowances should be calculated according to an allometric equation relating size to body weight (Jones et al., 2010; Petherick and Phillips, 2009).

Warriss et al. (2002) describe a survey in which they determined the stocking densities at which sheep are transported commercially in the United Kingdom. A total of 74 vehicles were assessed transporting 6500 sheep to a single slaughterhouse. Stocking densities were calculated as m^2 floor area available per 100 kg liveweight and were estimated from the dimensions of the vehicle pens and estimates of liveweight based on chest girth measurements. The observed stocking densities ranged from 0.29 to 2.00 m^2/100 kg liveweight, and the average density was 0.65 m^2/100 kg. One per cent of the sheep were carried at estimated stocking densities of less than 0.3 m^2/100 kg, 37% at densities between 0.3 and 0.6 m^2/100 kg and 57% at densities between 0.6 and 0.9 m^2/100 kg. Over 30% of the animals in the survey were transported at densities higher than the working recommendations made by the Farm Animal Welfare Council.

Jones et al. (2010) have addressed the debate concerning desirable stocking densities for sheep in transit to ensure animal welfare. The debate centres on the proposed advantages of low or high stocking density in relation to freedom to express normal behaviours versus postural instability. The study by Jones et al. (2010) studied these issues by measuring the incidences of loss of balance, slipping and falling at different space allowances during transport and the extent to which sheep show evidence of choosing to brace themselves against each other or to stand independently. Four categories of sheep, shorn and fleeced ewes and lambs, were transported at five space allowances on standard journeys of 6 hours. Minimum space allowance, low, was taken from legislation (whilst medium-low, medium-high and high allowances were calculated from the allometric equation $A = kW^{0.67}$ (W: average liveweight/pen and k: empirical constant). k-values of 0.021, 0.026, and 0.037 were used for increasing allowances and fleeced animals were given an additional 25% space. A control group providing more than 1m^2/animal was also included. It was demonstrated that sheep transported at control and high spacing suffered fewer losses of balance and slips than sheep transported at low and medium-low spacing, especially on roads with rough ride characteristics (B roads). Rates of falling were highest for shorn sheep in the low and medium-low spacing, where sheep were also forced to the floor by their pen-mates and unable to stand immediately. Sheep transported at control and high spacing were seen to stand close to, but not touching their pen-mates, bracing themselves against the motion of the vehicle by spreading their feet, not by leaning on their pen-mates. They were also seen to lie in transit at higher space allowances. The valuable information generated by that study indicates that the space provided by minimum legislation and calculations with a k-value of 0.021 are unacceptable, as they do not allow the sheep to adopt their preferred spacing strategy and lead to more losses of balance, slips and falls. Space provided by a k-value of 0.026 and above for shorn sheep and 0.033 for fleeced sheep, was better suited to this independent strategy and led to fewer losses of balance, slips and falls, which is considered better for the welfare of the sheep.

Stress related to journey duration and space allowance has been investigated by de la Fuente et al. (2012). Two journey durations, short (40 minutes) and long (4.8 hours) were considered at three space allowances of 0.12, 0.20 and 0.25 m^2 per lamb. Lamb behaviour was recorded continuously during the journeys and heart rate was monitored and blood samples obtained pre and post transport for determination of stress biomarkers. Meat quality measures were also made. Lambs stood for most of the time on both long and short journeys. However, the number of lambs undertaking each of the monitored behaviours was found to differ with journey time and space allowance. Heartrate increased with loading and transport. Cortisol, LDH, glucose, albumin and osmolality were higher in suckling lambs transported for a short time than for those transported for longer periods. Space allowance did not affect any of the blood parameters. It was proposed that the study indicated that short journeys induced higher stress responses in suckling lambs than long journeys. These observations may be attributable to the impact of loading and initial transport novelty and the time required for adaptation and stabilisation.

Cozar et al. (2016) have considered the interaction between transport space allowance or stocking density and lairage feeding practice in lambs transported to slaughter in Spain. Three stocking densities (low, medium and high) were employed and animals were either fed or fasted in lairage. It was concluded that a range of space allowances during transport between 0.16 and 0.30 m^2/lamb could be recommended that do not induce major changes in welfare physiological indicators and that feeding is preferable to fasting during the post-transport lairage period.

As for other species there is good evidence that stocking densities or space allowances for sheep and lambs should calculated according to an allometric equation relating size to body weight. The evidence indicates that the space provided by minimum legislation and calculations with a k-value of 0.021 are unacceptable, as they do not allow the sheep to adopt their preferred spacing strategy and lead to more losses of balance, slips and falls. Space provided by a k-value of 0.026 and above for shorn sheep and 0.033 for fleeced sheep, was better suited to this independent strategy and led to fewer losses of balance, slips and falls, which is considered better for the welfare of the sheep.

Thermal conditions and Ventilation

It has been proposed that ruminants have a wide range of thermos-neutrality from about 10 to 30°C (Webster, 1983), enabling them to tolerate moderate fluctuations in temperature quite adequately. Parrott et al (1999) employed radiotelemetry to monitor and record deep body temperature in sheep during exposure to different stressors. Loading and transportation of sheep for 2.5 hours produced a rise in core temperature that, in males, persisted for several hours. It was suggested that sustained increases in deep body temperature or changes in circadian temperature rhythms in healthy sheep may be a response to psychological distress and, therefore, indicative of poor welfare.

In ewes, transportation by truck was seen to produce a significant increase in rectal temperature which declined following unloading (Ingram et al., 2002). Mortality from heat stress during road transport rarely occurs in sheep, though it is essential that adequate ventilation is maintained on-board the vehicle (e.g. reducing the amount of time that the vehicle is stationary). For a given stocking density and vehicle design, the temperature–humidity index inside the transport vehicle generally increases when vehicles are stationary in proportion to the duration of the stop. Fisher et al. (2005) reported that during journeys in summer, stationary periods and an increase of external ambient temperature (>25°C) could induce thermal stress and be detrimental to sheep welfare.

During long-distance transport by sea, heat stress often presents a challenge to livestock when they are transported from cold to hot regions with little diurnal temperature fluctuation. Kadim et al. (2007) studies the effects of transportation (100 km) at high temperature (37°C) on physiological stress and meat quality parameters in two ages (6 and 12 months|) of Omani sheep. The transported sheep had significantly ($p<0.05$) higher cortisol, adrenaline, noradrenaline, and dopamine concentration levels prior to slaughter at both ages than the sheep that were not transported. Transportation significantly influenced the meat quality characteristics of three muscles. It was concluded that short-term pre-slaughter transport at high ambient temperatures can cause noticeable changes in physiological and muscle metabolism responses in sheep.

Generally, sheep cope with heat stress better than cattle (Caulfield et al., 2014), though the risk and rate of dehydration occur with increased thermal panting. A heat stress model was developed for the Australian livestock export industry in 2003 to estimate (and subsequently) minimise the incidence of heat stress mortality in livestock during voyages to the Middle East. The review and refinement of the model are described in the Meat & Livestock Australia publications (Eustace et al., 2009; Ferguson et al., 2008).

The effects of long distance transport on lambs have been examined recently by Miranda de la Lama et al. (2018). 7 month old lambs were transported for 20 hours in Mexico under winter conditions on a pot-bellied truck. The measurements made included deep body temperature and a number of stress and metabolic biomarkers e.g. plasma cortisol, glucose and creatine kinase (CK), and a higher neutrophil/lymphocyte ratio as well as meat quality parameters. Location on the truck affected the stress responses exhibited by the lambs. The authors propose a link between thermal stress during transport, elevated physiological indicators of stress and poorer meat quality.

Sheep cope well with a range of temperatures and mortality from heat stress during road transport rarely occurs in sheep, though it is essential that adequate ventilation is maintained on-board the vehicle (e.g. reducing the amount of time that the vehicle is stationary). Loading can cause a rise in body temperature indicative of stressful handling.

Transport Practices

Jarvis et al. (1996) have compared the effects of passage through markets with transportation direct from farm in relation to indices of stress, hydration state and injury. It was reported that sheep from distant markets had a significantly greater plasma osmolality than those from either farms or local markets. It was proposed that inadequate provision of water at each stage of the process had resulted in dehydration. In addition sheep from local markets had a significantly greater plasma cortisol concentration than those from farms. This was attributed to sheep from local markets being more stressed by either the environment or the handling in the lairage than those from farms. Although the occurrence of bruising was low and not all measurements of dehydration were affected by source. It was proposed that the welfare of sheep in transit might be improved by better handling and the provision of water in markets and shorter journey times to slaughter thus reducing the risk of injury and dehydration.

Bradshaw et al (1996) have compared the behavioural and cortisol response of pigs and sheep during transport. The study revealed that the behaviour of pigs and sheep during short road transport journeys differed markedly. Pigs became very travel sick. It was also noted that pigs re-ingested their vomit within five minutes of the end of a journey (indicating recovery time was rapid) and travel sickness may therefore be overlooked if animals are not unloaded immediately. Pigs spent most of their journey time lying down. The fact that pigs stood more on rough journeys may have been to alleviate the effects of travel sickness. In contrast, sheep did not become travel sick. They tended to stand in both conditions which may make them susceptible to sudden vehicle movement. Since they also walked more and engaged in social interactions (mainly aggressive head butts) on rougher journeys they may be particularly susceptible to bruising. There was little evidence of habituation to journeys, although sheep generally tended to lie down more during later journeys. Cortisol levels were higher for both pigs and sheep on rough journeys compared with smooth journeys and were much higher in both conditions compared with control. This indicated that both pigs and sheep were sensitive to the particular 'roughness' of the journey. While both species are sensitive to the 'roughness' of journeys they show a marked difference in their behavioural response to transport. Pigs are prone to travel sickness and may require space and a substrate in order to lie down, while sheep spend most of their time standing and also walk and socially interact (which may lead to bruising). The study demonstrated the importance of developing welfare guidelines which are species specific.

The importance of driver skills and training in the determination of stability and resting behaviour of sheep in transit has been described by Cockram et al. (2004). That study showed that 80% of losses in balance of sheep were attributable to driving events. Driving events may disrupt animal resting behaviour and rumination. The quality of the journey experienced by sheep in transit was greatly affected by driving style and driving events and consideration of these factors should be key in driver training an assessment.

Da Cuhna Lemea et al. (2012) have characterised the effects of transportation methods and pre-slaughter rest periods on cortisol levels in lambs (35 kg body weight). The study compared the effects of transportation (1.5 hours) in open and closed compartments. The rest periods post-transport were either 1 or 3 hours. The method of transport influenced in the cortisol concentration with lambs transported in the open system exhibiting higher plasma concentrations. After the resting period in the slaughterhouse, there was a decline in the plasma cortisol concentration, with the animals subjected to 3 hours of rest presenting the lower average value. It was proposed that lambs with a longer lairage period prior to slaughter had more time to recover from the stress of the transportation than those that waited 1 hour. It was concluded that visual access to the external environment during the transport may constitute a stressor and the resting period before slaughter was effective in reducing stress.

Miranda de la Lama et al. (2012) examined the impact of 2 transport systems on lamb welfare and meat quality. In one system animals were transported directly to slaughter whereas in the alternative system lambs were transported to a collection centre where they were unloaded, handled and graded before continuing transportation to the abattoir. The study was performed in Spain in winter and summer conditions. The total time for each journey including stops was 4 hours. Significant interactions ($P \leq 0.05$) between transport system and season in both welfare and meat quality were found. In general, lambs subjected to direct transport and stopover during winter had a more intense stress response and poorer meat quality than lambs transported during summer. However, direct transport during the cold season seemed to be the most stressful, compared to the rest of the groups, which was reflected in significantly higher levels of cortisol, lactate, glucose, neutrophil/lymphocyte ratio, higher pH24 and darker and tougher meat.

Teke et al. (2018) have examined the effects of lairage time on some blood biomarkers and meat quality after transportation for 30 minutes. Lairage periods of 0, 2 and 4 hours were compared. It was concluded that lambs may be slaughtered soon after arrival at the slaughterhouse (i.e. short post-transport lairage) if journey duration is short also.

> As sheep will usually travel standing, unless journeys are very long, they are more susceptible to driver behaviour or road conditions that can lead to loss of balance and falls. Improved driver assessments and training can improve the welfare of transported sheep. The benefits of a rest period in lairage seem to be related to journey length, although no clear conclusions can be reached.

Repeated Transport

Roussel et al. (2006) attempted to determine if repeated exposure to stressors of a different nature and intensity during the last 6 weeks of pregnancy modified the reactivity of ewes to their lambs and to humans after lambing. The selected stressors included 10 sessions of transport in isolation twice a week for 1 hour. A principal component analysis was used to identify groups of statistically interrelated measures which otherwise would have remained undetected. During the 1st and the 9th sessions, transport in isolation provoked a greater cortisol release in ewes than isolation alone. However, ewes from both treatments habituated to the treatment with time. During the tests performed 1 hour and 6 hours after parturition, a clear divergence in reactivity was observed between treatments: isolated ewes tried to maintain contact with their lambs in the presence of a human while transported ewes did not. The differences in ewe behaviour during challenge situations after lambing were probably not due to a weaker mother–young bond but to divergence in the effect of treatment during pregnancy on fear of humans: repeated isolation reduced fear of humans whereas repeated transport increased it.

Sea and Air Transport

When sheep are transported long distances by sea, there is a greater risk of a poor welfare outcome; however, the risk of an adverse animal welfare outcome is ultimately determined by a range of animal, management and environmental factors (Marahrens et al., 2011). The World Organization for Animal Health (Office International des Epizooties, OIE) has established standards for the health and welfare of animals being moved across national boundaries (Schipp, 2013). Mortality rate is the main measure of welfare used by the Australian live export industry for shipments of livestock by sea and air (Phillips and Santurtun, 2013). It is claimed that the main cause of death during sea transport is the inanition/salmonellosis complex which consistently accounts for about 75% of all sheep mortality on-board the vessel (Norris, 2005). However, for animals transported long distances, or retained on farms and feedlots for long periods after transport, measures such as increased disease incidence and reduced productivity can also provide an insight into the long-term welfare effects of the journey (Broom, 2005). Long-distance sea transport exposes livestock to similar stressors to those experienced during road, rail or air transport; however, there are few independent peer-reviewed studies of the increased risk of cumulative stress during the extended transport period. The recent reviews by both Phillips and Santurtun (2013) and Caulfield et al. (2014) highlight the paucity of data in this area.

A body of work from Australia has addressed the issues arising from sea transportation of sheep. The work has developed techniques for assessing or modelling the impact and effects of sea motion and the on-board environment experienced by sheep in transit and how theses factors impact upon sheep health and welfare. Santurtun et al. (2014) have developed a novel technique to study the impact of motion on sheep that facilitates modelling of sea movements on these animals. The system allows exposure of animals to the three most important motions, roll (sideways), heave (vertical) and pitch (fore-aft). Roll and pitch motions were created using a programmable flight simulator platform, and heave motion was simulated elevating the entire apparatus with an electric forklift. Two main methods were developed to investigate the effect of these motions on sheep behaviour, physiology, balance, body posture, heart rate variability, rumination and feed intake. The behaviour of sheep on the platform was similar to that which has been observed on ships. It is concluded that a detailed understanding of the responses of sheep to ship motion can be obtained by subjecting them to the different components of simulated transport using land-based equipment.

During long-distance transport by sea, the space allowance also needs to take into account an animal's ability to access feed and water. The Australian Standards for the Export of Livestock (ASEL) includes minimum space requirements for sheep, which are lower than those required by domestic codes of practice for confined sheep (Caulfield et al., 2014). Ferguson and Lee (2013) investigated the impact of the ASEL space allowance on animal welfare, concluding that the existing allowances were sufficient. However, it was suggested that a 10% increase in space allowance during the early part of the journey could have some benefits and should be investigated further.

Phillips (2016) has examined the central role of thermal stress in mortality in sheep during sea transportation from Australia to the Middle East and proposes that the increase in mortality associated with season is attributable to heat stress. It is suggested that the Australian government's estimate of the heat stress threshold of sheep is substantially higher than that observed under simulated live export conditions, which leads to an underestimate of the importance of heat stress in sheep on voyages where mortality is high. Improved temperature monitoring on ships and the creation of both a robust model of the impact of increased temperatures on sheep morbidity and mortality, and a heat stress scale for sheep would assist in understanding and addressing this welfare concern. The high risk to sheep exported from Australia during summer in the Middle East is sufficient to warrant consideration of restriction of trade during this period.

Navarro et al. (2017) have examined the effects of simulated sea motion on stepping movements in sheep. Sheep were exposed to three movement types, Pitch, Roll, and Heave, or a Control treatment, in pairs for 30 minute periods in a changeover design. The orientation and frequency of stepping movements was recorded from videos made during the treatments and heart rate responses were monitored. Heave produced the biggest stepping responses, in the forelimb. Sheep stepped most commonly straight forwards and backwards with the fore limbs, then forwards, backwards and sideways with the hind limbs. When they did make lateral stepping movements, they moved their feet more outwards than inwards, presumably as this maintained balance more effectively. Stepping movements were associated with reduced high frequency heart beats, suggesting an associated negative emotion. Sheep on the left side of the crate showed some evidence of greater stress than those on the right, regarding their limb movement preferences and heart rate variability responses. This may be because animals on the left side of the crate had no other sheep in their left eye vision, signals from which are processed by the right brain hemisphere and are associated with stress responses. In conclusion, when subjected to simulated ship movement, sheep produced stepping and heart rate responses that were connected and indicated negative emotions.

Santurtun and Phillips (2018) have evaluated the effects of regularity of ship movements on the behaviours and physiology of sheep in simulation studies. Sheep were restrained in pairs in a crate mounted on a moveable, programmable platform for 60 minute periods, changing treatments over 12 consecutive days. In an initial experiment a repeated speed of movement and change in angle (regular movement) was compared to variable angles and speeds (irregular movement) of roll, pitch or combined movements, for sheep behaviour, heart rate and feed and water intake responses. Feed intake was increased by irregular roll and pitch motion. During irregular sequences sheep affiliated more, with their heads one above the other and supported themselves against the crate or kneeling. Irregular sequences and combined roll and pitch synergistically increased stepping behaviour, indicating loss of balance, and heart rate, possibly indicating stress. Heat rate data demonstrated that the RMSSD band was reduced during irregular movement and LF/HF ratio increased during irregular sequences of roll and pitch suggesting less parasympathetic nervous system activity. It was proposed that irregular sequences and combined roll and pitch caused stress and increased activity to correct loss of balance, as well as increased affiliative behaviour. Separating sheep during irregular motion reduced body instability and stress, suggesting that close stocking is detrimental to their welfare.

Long-distance sea transport exposes livestock to similar stressors to those experienced during road, rail or air transport; however, there are few independent peer-reviewed studies of the increased risk of cumulative stress during the extended transport period. Motion experienced on a ship appears to cause sheep stress, particularly if close stocked. As with cattle the available data are few but to date do not support ferry transport being considered a rest period for sheep

Welfare Measures and Outcomes

Parrott et al. (1999) employed radiotelemetry to monitor and record deep body temperature in sheep during exposure to different stressors. Loading and transportation of sheep for 2.5 hours produced a rise in core temperature that, in males, persisted for several hours. It was suggested that sustained increases in deep body temperature or changes in circadian temperature rhythms in healthy sheep may be a response to psychological distress and, therefore, indicative of poor welfare.

Ingram et al. (2002) investigated the effect of transport on core and peripheral body temperatures and heart rate in 18-month-old ewes. Manual recordings of rectal temperatures were obtained, and automated logging of peripheral (external auditory canal and pinna) temperatures and heart rate was carried out. Transport produced a significant increase in the rectal temperature, which declined following unloading.

Peripheral measures of body temperature also exhibited changes with transport. However, both ear-canal and pinna temperatures declined during actual transport, reflecting to some extent the decline in ambient temperatures recorded externally by sensors on the ear tags of the animals. It was suggested that peripheral measurement of temperature may offer potential as a technique for the long-term monitoring of thermal responses to stress.

Welfare assessment in transported sheep on commercial road journeys generally involves the characterisation of physiological responses (Cockram et al., 2000), behavioural responses (Wickham et al., 2012), injuries (and mortality) and carcass quality (Dalmau et al., 2014). Sheep show less obvious signs of distress during road transport than other species of farm animals (Broom, 2008). However, there are some indications that sheep may still find the experience aversive (Cockram, 2007; Parrott et al., 1994). Conditions within vehicles during transportation can also affect the stress response in sheep, with particular stressors including exposure to high levels of noise, handling by humans, flooring, vibration and altered thermal environment (Broom, 2008). There has been little research to identify the importance of each of these individual components during prolonged transportation.

Llonch et al. (2015) have performed a systematic review of welfare indicators that might be employed to assess sheep welfare on farm, during transport and at slaughter. The study identified 48 animal-based indicators of sheep welfare that were categorised by the Five Freedoms. Their validity as measures of welfare and feasibility for use in abattoirs were evaluated as potential measures of prior sheep welfare on the farm of origin, at market, or during transportation to the abattoir. A total of 19 indicators were considered valid, of which nine were considered theoretically feasible for assessing sheep welfare at abattoirs; these were body cleanliness, carcass bruising, diarrhoea, skin lesions, skin irritation, castration, ear notching, tail docking and animals recorded as ‘obviously sick’. It was suggested that novel welfare indicators are needed to assess short-term hunger and thirst, prior normal behaviour and long term fear and distress.

Messori et al. (2015) have developed a welfare assessment tool for application to sheep after long distance transport. The protocol included outcome (animal-based measures) and input variables (resource-based and management-based measures), being welfare-relevant aspects of both transport and unloading procedures. The protocol was tested on 40 commercial transports arriving at previously selected assembly centres and slaughterhouses in Italy and Greece. The protocol was found to be feasible when applied to commercial transports, allowing for a comprehensive and quick sheep welfare assessment during unloading, without impairing stockman work. Univariate analysis was carried out to evaluate associations between outcome and input variables. Significant association between outcome measures and risk factors were identified when associated to unloading procedures but not to travel conditions.

Wickham et al. (2016) have validated the use of qualitative behavioural assessment (QBA) in sheep using controlled experimental conditions (using transport as a challenge) and comparing assessments against physiological variables. The behavioural expression of 14 Merino wethers, which had never experienced land transport, were assessed during their first road event (naïve to transport), and then again on their seventh event 8 days later (habituated to transport). Blood samples were collected immediately before loading and after unloading, and heart rate and core body temperature were measured continuously throughout each event. Continuous video footage recorded during each event was used to provide clips of individual animals that were shown to observers for QBA. There was significant consensus ($P < 0.001$) amongst 63 observers in terms of their assessment of the behavioural expression of the sheep. Transport-naïve sheep were assessed as being more ‘alert’, ‘anxious’, and ‘aware’, whereas transport-habituated sheep were more ‘comfortable’, ‘tired’, and ‘confident’ ($P = 0.015$). Heart rate and heart rate variability, core body temperature and a stress leukogram were greater ($P < 0.05$) in sheep during the first (naïve) event compared with the habituated event, and were significantly correlated with the QBA scores ($P < 0.05$). It was concluded that QBA is a valid, practical and informative measure of behavioural responses to transport.

Pascual-Alonso et al. (2016) characterised the thermo-physiological, haematological, biochemical and behavioural stress responses of sheep transported by road. Thermo-physiological profiles of ewes were measured by temperature buttons. Direct observations, with a combination of scan and behaviour sampling, were carried out to collect information on individual behaviour and the time it took the ewes to drink water, eat and rest after returning to their pen respectively. Transported ewes lost approximately 1 kg live weight compared to controls and had higher body temperatures until 12 h post-transport. Cortisol, glucose, non-esterified fatty acid (NEFA) concentrations as well as the neutrophil–lymphocyte ratio (N/L) and other physiological indicators were higher immediately after unloading in transported ewes but mostly returned to normal after 4 hours, with complete recovery after 24 hours. Behavioural analysis post-transport demonstrated that transported ewes chose to eat before drinking and spent less time resting than controls in the first 3 hours after unloading. It was concluded that even short-journey durations may induce behavioural, physiological and thermo-physiological responses indicative of significant stress, leading to live weight shrinkage and losses.

Published studies have used plasma / blood concentrations of cortisol, glucose, non-esterified fatty acid (NEFA) as well as the neutrophil–lymphocyte ratio (N/L) all of which are altered in sheep by transportation and may reflect thermal stress as well as the impacts other transport stressors. Qualitative behavioural assessment (QBA) has also been employed in sheep in controlled experimental conditions (using transport as a challenge) and comparing assessments against physiological variables.

Other issues

Welfare at markets

Gregory et al. (2009) reported that though the prevalence of handling difficulties at sheep markets was low this did not indicate that there were inherent welfare problems. Older studies have proposed that transit through markets results in increased dehydration and fatigue (Kim et al., 1994), increased carcass bruising (Knowles et al., 1994a) and increased mortality during transport and in lairage (Knowles et al., 1994b).

Post Transport Lairage

There is an underlying assumption that the longer the rest period, the better. However, for pre-slaughter lairage it appears that a period between 6 and 12 hours may be optimal (Liu et al., 2012), when comparing white blood cell counts and differentials, plasma cortisol, creatine kinase and glucose of sheep transported for 8 hours, then lairaged for 0, 2, 6, 12, 24 or 48 hours with un-transported sheep. Similarly, Ekiz et al. (2012) found that cortisol levels in sheep that allowed a 30 minute rest period were not significantly different from those that allowed an 18 hour rest period, but meat quality attributes (tenderness, colour, water holding capacity and cooking loss) were better in the group held for 18 hours. Liste et al. (2011) also found elevated plasma cortisol, lactate and glucose levels in lambs slaughtered immediately after arrival compared to lambs rested for 12 hours, while Leme et al. (2012) confirmed that even a short 3 hour lairage period can reduce the cortisol response in sheep, suggesting a recovery from transport and handling stress.

> Behavioural analysis post-transport demonstrated that transported ewes chose to eat before drinking and spent less time resting than controls in the first 3 hours after unloading. It was concluded that even short-journey durations may induce behavioural, physiological and thermo-physiological responses indicative of significant stress, leading to live weight shrinkage and losses. Even a short recovery period (3 hrs after 12 hrs of transport) can reduce animal stress.

Animal handling

There is an abundance of scientific evidence to demonstrate that stress during animal movement and the risk of physical injury can be minimised by ensuring that the animal handling facilities are well designed. The impact of poorly designed or constructed handling facilities on the welfare of livestock has been studied extensively (Grandin, 2009). Provision of non-slip floors, well-designed races and even lighting throughout the movement areas, together with the elimination of distractions, have been shown to improve the movement of sheep in abattoirs. Movement difficulties are mostly created by poor physical conditions such as inappropriate flooring or raceways. This can be assessed practically in a processing plant by recording slips, falls and baulking as livestock are moved through the handling system (Grandin, 2012).

Stockperson behaviour during handling such as frequency of touching, pushing and whistling influences cortisol concentration (Hemsworth et al., 2011). Similarly, the use of dogs has a pronounced effect on stress indicators in sheep. Grandin (2009) recommends that dogs should be limited to pastures, large pens and other open areas where animals have room to move away. Stockpersons, who believe that electric prodders or goads and dogs are appropriate methods for moving animals and that the use of goads does not stress animals, may use goads more frequently (Coleman et al., 2012). In Australia, electric prodders are still widely used in the sheep transport industry (Burnard et al., 2015) and permitted in most jurisdictions. Within the abattoir, their use is usually limited to moving reluctant sheep into restraint (Grandin and American Meat Institute Animal Welfare Committee, 2013).

Lairages can be relatively noisy, especially when compared with most farm environments. Weeks (2008) found noise levels in sheep lairages to be lower than in pig and cattle lairages, but higher than sheep would normally be accustomed to if out in a paddock. Noise, such as banging gates, use of rattles, dogs barking and whistling, can have a profound effect on animal movement and stress levels (Kim et al., 1994). Unlike cattle, sheep generally do not vocalise in response to an aversive stimulus; therefore, this is not a measurable indicator of stress during handling. Apart from vocalisation between ewes and their lambs, or vocal communication between sheep, there has been little research in this area.

Sheep find handling, particularly rough handling, noise and the presence of dogs stressful in lairage and during loading and unloading. Training in appropriate handling practices could minimise these sources of stress.

GOATS

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). 'Good practices for animal transport in the EU (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have not specifically identified issues or the main areas of welfare concern for the transport of goats. It may be safely assumed, however, that the concerns relating to the other livestock species including sheep will be relevant to the transportation of goats. Therefore it is considered appropriate to treat this species in the same manner according to the welfare risks identified for other species.

Thermal conditions and Ventilation

Kadim et al (2006) have studied the effects of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics of three breeds of Omani goats. Forty-two male goats (12 months of age) representing equally three breeds of Omani goats (Batina, Dhofari, and Jabal Akhdar) were divided into two groups. One group was exposed to 2 h transportation stress (TS) and a second group (control) was not transported (NT). The TS group was transported on the day of slaughter for 100 km in an open truck. The average temperature during transportation was 37ºC. All animals were blood-sampled before loading and prior to slaughter via jugular venepuncture. The TS goats had higher plasma cortisol, adrenaline, nor-adrenaline, and dopamine concentrations than NS goats. Blood serum from Batina goats had significantly higher cortisol, adrenaline and dopamine and nor-adrenaline concentrations than those from Jabal Akdhar goats. Transportation stress had also a significant negative effect on meat quality characteristics. It was proposed that subjecting goats to the 2-hour road transportation with high ambient temperatures can generate major physiological and muscle metabolism responses.

Transport Practices

Das et al (2001) have studied the standing behaviour and orientation of goats during short distance transport. The most common orientation selected by goats was parallel to the direction / axis of travel or truck followed by a diagonal orientation with the least favoured being perpendicular to hat axis. Orientation changed frequently to facilitate maintenance of balance. Most disturbances in postural stability were associated with driver actions i.e. rapid acceleration or breaking and cornering. It was proposed that ensuring a calm and measured driving style is key to avoiding falls and excessive effort for postural stability and that this will reduce both stress and injury and will improve carcase quality in slaughter goats. Perhaps the preferred orientation of goats in transit should be considered in future vehicle and pen design.

Ali et al (2006) have investigated the stress associated with road transportation in desert sheep and goats, and the effect of pre-treatment with xylazine or sodium betaine. The study showed that road transportation for 2 h resulted in variable and statistically insignificant increases in heart, pulse and respiratory rates in both control and experimental animals. Transportation stress significantly increased the concentrations of plasma cortisol, and glucose, and decreased that of magnesium.
The endogenous thiocyanate concentration was unaffected. The stress also insignificantly decreased the haematocrit (PCV), and the number of lymphocytes, and increased the concentration of haemoglobin. Pre-treatment of sheep and goats with xylazine at a single dose of 0.01 mg/kg by the intravenous route significantly ameliorated the effects induced by the stressful stimulus. The effects of pre-treatment of the two species with sodium betaine (10 mg/kg) produced variable and insignificant effects.

Ayo et al (2006) examined the excitability scores of goats administered ascorbic acid and transported during hot-dry conditions. Excitability scores were recorded for each goat; when weighed, before, immediately after, and 3 h after 8 h of transportation. A score of one to four was allocated to each goat; higher scores represent greater excitability. Immediately after transportation, excitability scores decreased significantly, especially those of control goats. At 3 h post-transportation, the excitability scores of animals in the experimental group were not significantly different from their pre-transportation normal values, whereas those of control goats were significantly lower. The correlation i.e. the relationship between excitability score values and percent excitability (percentage of goat with particular excitability score) for different excitability score group 3 h post-transportation was positive and highly significant in both experimental and control goats. It was suggested that road transportation induces considerable stress (depression) in goats as evidenced by a lower excitability score post-transportation. Moreover, the administration of Ascorbic acid / Vitamin C pre-transportation facilitated the transition from a state of depression to excitation. In conclusion, AA administration to animals prior to transportation may ameliorate the depression often encountered after road transportation.

Minka and Ayo (2007) have examined the potentially beneficial effects of supplementation with vitamin C upon transport stress in goats during hot weather. Ten goats were treated orally with ascorbic acid served as experimental subjects, while seven goats treated with sterile water served as the control. The goats were transported for 8 h. The ambient temperature and relative humidity during the study period fluctuated between 21 and 38°C and 51 and 91%, respectively, which indicated that the season was thermally stressful. The rectal temperature obtained in the control goats was significantly higher than the value in the experimental goats after transportation. There was a significant decrease in eosinophil counts and an increase in neutrophil counts and neutrophil:lymphocyte ratio recorded in the control goats after transportation, which suggested that the control goats were physically and emotionally stressed. The control goats lost 11.9% of their initial liveweight, while the experimental goats lost only 1.04% after transportation. Multiple stresses, including extreme thermal conditions induced physiological stress upon the transported goats and impaired their homeostatic mechanism. Vitamin C administration in goats may reduce the adverse effects of road transportation stress.

Ayo et al (2009) have reported plasma electrolyte disturbances induced by transportation of goats in the hot dry season in Nigeria. Transportation heat stress was associated with changes in plasma cation concentrations and respiratory alkalosis, dehydration and muscle damage. Administration of ascorbic acid or vitamin C was reported to alleviate the electrolyte disturbances. It is difficult to extrapolate from these findings to recommendations for better practice to reduce welfare risks in goat transport other than to suggest that the thermal environment is a key risk factor and that administration of ascorbic acid may afford some symptomatic protection.

Further studies on the effects of ascorbic acid / vitamin C on transport stress in goats have been performed by Minka et al (2009). In this study 60 adult Red Sokoto goats transported by road for 12 h. The calculated behavioural scores were validated with specified objective physiological indices of stress during the post-transportation period in experimental (administered ascorbic acid (AA)) at a dose of 100 mg/kg body weight before transportation) and control (given sterile water only) goats. The behaviours of slips, falls, and jumps and time spent on each event, and the calculated behavioural points per goat during handling were significantly higher than the corresponding values recorded during loading and unloading. Handling was the most stressful and displayed the poorest behavioural score compared to loading and unloading. Overall 60% of handling and loading procedures were associated with scores of 1–2 points, while 12% displayed scores of 2.1–3 points and 28% displayed scores of 3 points. Unloading was less stressful with 90% of the goats displaying the score of 1–2 points. The behavioural scores in experimental and control goats were not different. The relationships between the behavioural scores and indices of
stress were positive and very significant in the control goats, which showed that the higher and poorer the behavioural points and scores recorded during handling and loading, the higher were the values of the physiological indices of stress (rectal temperature, neutrophil/ lymphocyte ratio and the percent liveweight loss) recorded in the post-transportation period. In AA-treated goats, the relationships were less or insignificant, and this demonstrated that AA reduced adverse effect, of the stresses imposed on the goats by the handling, loading and transportation. It was concluded that the scoring method adopted in the present study may be of value in the assessment of welfare of goats before being transported, and the risk of increase in morbidity and mortality may be reduced by adjusting transportation conditions. If

transportation is essential it is recommended that AA be administered to goats prior to commencing the journey. The value of this procedure in reducing stress as opposed to decreasing apparent responses to stress must be considered.

Zulkifli et al (2010) have characterised the physiological responses in goats subjected to road transportation under the hot, humid tropical conditions. In this study the influence of two different stocking densities (0.20 m^2/animal and 0.40 m^2/animal) in transit under the hot, humid tropical conditions on blood parameters and body temperature were investigated in 30 Boer does. The animals were road transported for 3 h and the control group was kept under normal conditions in the farm. Irrespective of stocking density, transportation increased rectal temperature, serum levels of cortisol and glucose and neutrophil to lymphocyte ratios (NLR). Higher stocking density was more stressful to the goats based on NLR. Transportation had no significant effect on serum creatine kinase activity. It was suggested that irrespective of stocking density, transportation under the hot, humid tropical conditions imposed a severe stress on the goats.

Minka and Ayo (2012) have reported assessment of thermal loads on transported goats treated with ascorbic acid during the hot-dry conditions Panting score (PS), rectal temperature (RT), heart rate (HR) and respiratory rate (RR) were employed as reliable stress indices to assess the effects of different thermal loads, measured as temperature humidity index (THI), encountered in the vehicle during 12 h of road transportation of 40 goats. Treated goats received 100 mg/kg body weight of ascorbic acid (AA) as an ameliorating agent. It was shown that PS, RT, HR and RR increased above normal reference values with increase in the THI and journey duration. The rise in PS value, which is a visual indicator of the severity of thermal load, was the most pronounced. It was suggested that values of THI in the vehicle up to 94.6 constitute no risk, whilst values of or above 100 represent risk of moderate to severe stress. The relationships between the thermal load and the physiological variables were positive and significant. They reflect the degree of stress imposed by each THI value during the transportation, and may be used as recommended ranges and limit thermal load values in transported goats. The results demonstrated that administration of 100 mg/kg body weight of AA before road transportation mitigated the risk of adverse effects of high THI values and other stress factors due to road transportation in goats. Again a key consideration must be the difference between amelioration of symptoms as opposed to the prevention of stress.

Minka and Ayo (2013) have characterised also the physiological and behavioural responses of goats to 12-hour road transportation, lairage and grazing periods, and the possible modulatory role of ascorbic acid (AA). Experimental goats were given AA, whereas control goats received sterile water before transportation by road for 12 hours. Excitability scores, grazing time, liveweight, and activities of serum enzymes were evaluated in goats that were grazed and those kept in lairage post-transport. It was shown that 12 hours of road transportation and lairage was stressful to the goats, and it decreased their excitability scores, grazing time, and liveweight. The activities of alanine aminotransferase, aspartate aminotransferase, and creatine phosphate kinase rose after the transportation, especially in the control goats, kept in lairage. Overall, the results showed that extensively raised goats, transported for 12 hours during the hot-dry season, require a lairage period of 7-11 days for their metabolism, behaviour, and live-weights to return to baseline values. Goats that were allowed to graze after transportation required 3 days to return to baseline values, but those administered with AA before transportation and grazed after transportation required only 2 days to recover. It was proposed that that keeping goats in the lairage after transportation was not beneficial. In conclusion, AA administration ameliorated stress because of transportation by road, and post-transportation grazing facilitated the recovery of the goats from the stress.

Welfare Measures and Outcomes

The physiological effects of repeated transport in pregnant goats and their offspring have been investigated by Duvaux-Ponter et al (2003). The study attempted to determine if repeated exposure to prenatal stress resulted in alterations in the hypothalamic-pituitary-adrenocortical (HPA) axis and the sympatho-adreno-medullary (SAM) system of their offspring. Twenty-six goats were assigned to one of two treatments during the last five weeks of gestation: 9 series of 55 min of transport or no transport. During transport, the goats were physically and visually isolated from their congeners. Transport in isolation induced a large increase in plasma concentrations of cortisol, glucose and non-esterified fatty acids, which confirms that it is a very stressful situation for goats. Moreover, the goats did not become accustomed to the stressor. Gestation length, birth weight, litter weight and growth of the kids were not modified by treatment. Cortisol concentrations tended to be higher in prenatally stressed kids than in control kids 1 h after birth and the opposite was observed at 48 h of age. Indeed, the decrease in cortisol concentrations between 1 and 48 h was greater in prenatally stressed kids than in control kids (time × treatment interaction. The effect of prenatal stress on the HPA axis did not persist, since in older kids cortisol concentrations were not modified by treatment. At one month of age, prenatally stressed kids showed a higher medulla weight and tended to show a higher phenyl-ethanolamine N-methyl transferase activity than control kids. It was proposed that repeated transport in isolation is an important stressor in pregnant goats and can affect the HPA axis and the SAM system of their offspring.

Aoyama et al (2008) investigated the physiological effects on goats of transportation for one hour in a small truck and examined also the food and water consumption of the animals after transportation. Eight adult goats (four castrated males and four ovariectomized females) were used. Plasma levels of cortisol, glucose and free fatty acids increased significantly within 15 min of the start of transportation, and these higher levels were maintained throughout transportation. These results indicate that transportation in a small truck activates the hypothalamus-pituitary-adrenal (HPA) axis and the sympathetic nervous system in goats. Despite activation of the sympathetic nervous system, heart rate (HR) in subjected animals during transportation did not differ from during the control animals, which were housed in their usual pen. However, after the transportation had ended and the goats started to eat fodder, HR increased significantly. There was no difference in the amount of food consumption between the control and transported goats. Water consumption in the first three hours after transportation was significantly lower in the transported goats than in the controls for the equivalent period. In the subsequent three hours, however, the transported goats consumed more water than the controls. Consequently, the total water consumption of the transported goats did not differ from that of the controls during the six hours after transportation. In conclusion, short-term transportation with a small vehicle activated the HPA axis and the sympathetic nervous system in goats. HR was not increased during transportation, but after the transportation had ended HR in transported goats was higher than that in control goats. After transportation, goats had consumed the same amount of food as control goats, but water consumption during three hours after the transportation was lower than that of control goats.

Aoyama et al (2008) investigated the physiological effects on goats of transportation for one hour in a small truck and examined also the food and water consumption of the animals after transportation. Eight adult goats (four castrated males and four ovariectomized females) were used. Plasma levels of cortisol, glucose and free fatty acids increased significantly within 15 min of the start of transportation, and these higher levels were maintained throughout transportation. These results indicate that transportation in a small truck activates the hypothalamus-pituitary-adrenal (HPA) axis and the sympathetic nervous system in goats. Despite activation of the sympathetic nervous system, heart rate (HR) in subjected animals during transportation did not differ from during the control animals, which were housed in their usual pen. However, after the transportation had ended and the goats started to eat fodder, HR increased significantly. There was no difference in the amount of food consumption between the control and transported goats. Water consumption in the first three hours after transportation was significantly lower in the transported goats than in the controls for the equivalent period. In the subsequent three hours, however, the transported goats consumed more water than the controls. Consequently, the total water consumption of the transported goats did not differ from that of the controls during the six hours after transportation. In conclusion, short-term transportation with a small vehicle activated the HPA axis and the sympathetic nervous system in goats. HR was not increased during transportation, but after the transportation had ended HR in transported goats was higher than that in control goats. After transportation, goats had consumed the same amount of food as control goats, but water consumption during three hours after the transportation was lower than that of control goats.

Several studies have evaluated transportation stress in goats, often in extreme thermal conditions. Subjecting goats to even 2-hour road transportation with high ambient temperatures can generate major physiological and muscle metabolism responses. As in other species driving style and animal arrangement on the vehicle can influence the welfare of transported goats. The preferred orientation of goats in transit should be considered in future vehicle and pen design. However, there is little reliable evidence on which to base policy or guidance pertinent to the carriage of goats.

POULTRY

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). 'Good practices for animal transport in the EU: poultry' (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have identified the main areas of welfare concern for the transport of poultry species. These areas have been addressed through identification and integration of recommendations for good and best practice from scientific knowledge, scientific literature, experiences and information from stakeholders.

It is proposed that during transportation, various factors are deemed important to ensure bird comfort and welfare. These differ when transporting chicks compared to end-of-lay hens or broilers. For example it is necessary to pay special attention in order to avoid bone injuries in end-of-lay hens due to poor catching and handling conditions. As turkeys are heavy to handle, it is essential to catch them correctly and carefully. It is essential also to ensure good functioning of ventilation systems (passive or mechanical) as these are essential to protect birds from heat or cold stress during transport. Ventilation and environmental control will be particularly important when transporting chicks or young birds or birds with poor feathering, e.g. spent laying hens in cold conditions, to avoid hypothermia, stress and mortality in transit. In hot conditions adequate ventilation is essential to dissipate heat and moisture loads to avoid hyperthermia, stress and increased dead on arrivals (DOAs). Poultry may be transported for up to 12 hours without provision of feed or water (EC 1/2005) and this may constitute an important welfare issue particularly if the thermal micro-environment is poorly controlled or in extreme weather conditions.

Schwartzkopf-Genswein et al (2012) have reviewed road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: The main effects of loading density, trailer microclimate, transport duration, animal size and condition, management factors including bedding, ventilation, handling, facilities, and vehicle design were summarized by species. The main risk factors listed above all have impacts on welfare (stress, health, injury, fatigue, dehydration, core body temperature, mortality and morbidity) and carcass and meat quality (shrink, bruising, pH, colour defects and water losses) to varying degrees. It was concluded that road transport of livestock is a multi-factorial problem where a combination of stressors rather than a single factor is responsible for the animal's well-being and meat quality post transport. Animals least fit for transport suffer the greatest losses in terms of welfare and meat quality while market ready animals (in particular cattle and pigs) in good condition appear to have fewer issues. More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions. Future research needs to focus on controlled scientific assessments, under NA conditions, of varying loading densities, trailer design, microclimate, and handling quality during the transport process. Achieving optimal animal well-being, carcass and meat quality will entirely depend on the quality of the animal transport process.

Chick transport

Chicks are transported mainly by road or, in the case of breeder birds, by air and road to these destinations. Chicks may be moved over relatively short distances in small numbers (e.g. pedigree birds, great grandparent lines) in high specification containers and vehicles or over much greater distances in less sophisticated systems. This first journey may be regarded as a major threat to the welfare and later production efficiency of all birds. It is widely recognized that the husbandry of the birds during this period and the conditions under which they are maintained immediately prior to and after placement are vital in determining subsequent welfare, performance and health status (e.g. Decuypere et al., 2001; Langhout., 2001).

Transport is regarded as a major source of stress and reduced welfare in all species at all ages including poultry and a major cause of these problems is the thermal micro-environment in transit (Mitchell and Kettlewell, 1998; Cockram and Mitchell, 1999; Mitchell et al., 2001a; Hunter et al., 2001; Kettlewell and Mitchell, 2001; Nilipour, 2002). Many other factors may also contribute to transport stress such as handling, feed and water withdrawal, vibration, space restrictions upon behaviour, noise and pollutants (Weeks and Nicol, 2000; Mitchell et al., 2001b). A small number of studies have addressed some aspects of the transportation environments of day old chicks but with a primary focus of minimising in-transit losses and maximising subsequent performance. Transport conditions for one day old chicks have been reported as influencing subsequent incidence of ascites and "sudden death syndrome" (Maxwell and Robertson, 1998).

Broilers turkeys and laying hens

There is evidence that the collecting, transport and handling of broilers is stressful (Duncan, 1989), leading to fear, as evidenced by tonic immobility measurements (Cashman *et al*., 1989). This is also seen in culled hens (Mills and Nicol, 1990). Handling, crating and transport of broilers are associated with physiological changes in the birds indicative of stress (Kannan and Mench, 1996; Freeman *et al*., 1984; Mitchell *et al*., 1992).

In transit the birds may be exposed to a variety of potential stressors including the thermal demands of the transport micro-environment, acceleration, vibration, motion, impacts, fasting and withdrawal of water, social disruption and noise (Nicol and Scott 1990; Mitchell et al., 1992; Mitchell and Kettlewell, 1993; Mitchell and Kettlewell, 1998). Each of these factors and their various combinations may impose stress upon the birds in transit but it is well recognized that thermal challenges and in particular heat stress constitute the major threat to animal well-being and productivity (Mitchell and Kettlewell, 1998; Mitchell et al., 2000; Weeks and Nicol, 2000; Mitchell et al., 2001; Nilipour, 2002). Birds may suffer from thermal stress during transport. (Kettlewell et al., 1993; Webster et al, 1993) and heat stress is thought to be a major factor in deaths (Bayliss and Hinton, 1990). Mortality is also increased with increasing journey time (Warriss et al., 1992). The imposition of thermal loads upon the birds in transit will thus result in moderate to severe thermal stress and consequent reduced welfare (Mitchell et al., 1992; Mitchell and Kettlewell, 1998; Mitchell et al., 2001), increased mortality due to either heat or cold stress (Hunter et al., 2001) and induced pathology including muscle damage and associated changes in product quality (Gregory, 1998; Mitchell, 1999).

Mortality is also increased with increasing journey time (Warriss et al., 1992). Birds may suffer physical damage, especially during catching, this taking the form of broken bones, bruising and haemorrhaging (Nicol and Scott, 1990; Knowles and Broom, 1990; Warriss and Knowles, 1993; Warriss et al, 1999; Weeks and Nicol, 2000). It is generally not known which of the various potential stressors imposed on birds in transit and during the associated handling procedures is perceived by the birds to be most important. Recent work (MacCaluim et al., 2003) suggests that when broilers are presented with both thermal and vibration potential stressors at the same time they find only the thermal stress aversive.

Mortality

Weeks and Nicol (2000) suggested a conservative figure for overall average mortality during the transport of broilers as 0.3%. Very high mortality rates are occasionally recorded. Swarbrick (1986) cites a case of 26% mortality of culled hens, and Warriss et al. (1992) recorded a case of 15% mortality of broilers, in single loads. Because of the numbers of birds transported, these percentages translate into very large absolute numbers of birds dead on arrival (DOA) at the processing plant whose welfare has been severely compromised. A major causal factor is heat stress, but many birds also die of traumatic injuries (Gregory and Austin, 1992). Reduced mortality will therefore result from closer control of environmental conditions during transit and more careful bird handling to reduce trauma (Warriss et al, 1999). It will also result from shorter journey times (Warriss, et al., 1992).

Even at a rate of 0.2 –0.3% mortality, this is much higher than would be expected in non-transported birds. Based on published figures for mortality during the rearing period, Warriss (1996) estimated that journeys of up to 4 hours increased mortality by about ten-fold and journeys over 4 hours nearly 19-fold. More recent studies (Hunter et al 1997; 2001) have examined the causes and distributions upon the vehicle of DOAs during commercial broiler transportation during different times of the year. A total of 26 journeys were studied using both curtains open and curtains closed configurations at the appropriate times of the year. The findings indicated that, as might be predicted, mortalities due to existing pathology or catching injury were randomly distributed across the bio-load and were unaffected by season. By contrast, those attributable to transport stress had very high incidences in specific locations upon the vehicle. In the curtains open configuration overall mortality was low (0.12%) and up to 90% of this figure was attributable to pathology and physical damage or injury. On journeys employing the curtains closed configuration mortalities as high as 0.93% were recorded and 95% of these were a consequence of "transport (chiefly thermal) stress". The vast majority (>75%) of these DOAs came from the "thermal core" of the vehicle (heat stress) or close to the air inlets of lorry and trailer (cold stress). The findings point to a role for the passive ventilation regime and its efficiency in determining the local thermal micro-environment and the degree of stress imposed and consequent mortality.

The transportation of poultry will now be considered under the headings identified above and derived from the structure of EC 1/2005 and associated annexes.

Fitness for Transport

Current European and UK legislation state that no animal shall be transported unless it is fit for the intended journey (EC 1/2005). For several livestock species guidelines have been developed to support pre-transport inspection and the assessment of fitness to travel but at the present time no similar scientifically based guidelines for poultry are available (Jacobs et al., 2017). Good Practice Guidelines have recently been published (GGP, 2018) which present practical advice for pre-transport inspection of broiler chickens. Inspection of large numbers of broiler chickens prior to transport to slaughter presents many practical and logistical difficulties including identification of those persons responsible for the inspection or assessment procedure. Jacobs et al. (2017) determined fitness for transport in broilers on the basis of identification of pre-loading lameness, illness, hock burns, foot-pad dermatitis, lesions, physical defects, cleanliness and cachexia. Birds deemed unfit on this basis exhibited higher post-transport indicators of stress and there were significant interactions with stocking density. It was recommended that the approach should constitute the basis of more structured and rigorous assessment of fitness for transport in commercial practice.

Journey Times (Chicks)

Until recently there has been a recognised paucity of information relating to the scientific basis for prescribed transport times for newly hatched chicks. Current European legislation prohibits (EC 1/2005) journeys of greater than 24 hours unless adequate food and water are provided. Such journeys should be completed within 72 hours of hatching.

Valros et al. (2008) examined the effects of journey times on the behaviour of newly hatched chicks from 2 strains of laying hen. The study assessed the effects of long transport durations on subsequent growth, the development of perching behaviour, fear of humans (measured as the duration of tonic immobility induced by manual restraint) and the willingness to compete for access to feed. Journey times of 4 hours and 14 hours were compared in simulated transport trials. The results were inconclusive with no clear indication that indication that long transport of day old chicks has significant wide reaching effects on behavioural development.

The effects of journey time for newly hatched chick transport upon hydration state, mortality, production performance, and development and incidence of pododermatitis during the grow-out period have been studied by Bergoug et al. (2013). Three transport durations were employed. The treatments were less than 5 min (no transport) or 4 or 10 hours of transportation. Transportation duration affected body weight up to 21 days of age with control chicks exhibiting better growth and a significantly higher body weight than transported chicks. No clear effect on haematocrit, feed uptake, feed conversion ratio, or mortality was observed for birds transported up to 10 hours. The decrease in weight in 10 hour transported chicks birds was associated with less severe pododermatitis.

Khosravinia (2015) examined the effects of journey length upon weight loss and residual yolk utilisation in newly hatched chicks. Journey distances between 200 and 1000km were examined and biochemical and physical measures compared to hatchery values. Live weight decreased linearly by 0.42 and 0.48 g per 100 km of journey in males and female chicks, respectively. Yolk sac residual utilised by 0.071 and 0.069 g per 100 km of travel in males and females chicks, respectively, over journey distances up to 800 km. Extended journeys from 800 to 1000 km caused a greater decline of 0.51 and 0.58 g per 100 km in yolk weight in male and female chicks, respectively. On journeys over 1000 km, serum glucose level was decreased by 40%. Long distance transport imposes greater physiological stress than shorter journey times.

Jacobs et al. (2017b) examined the effects of journey duration and parent flock age upon the stress and chick quality responses of newly hatched broiler chicks. The study reported that there was no effect of flock age on the stress response of the chicks and no alterations to permissible journeys times based on flock age are required. As with previous reported studies (Mitchell, 2009) increased journey time was associated with adaptive physiological responses which may be primarily attributed to the duration without food. Thus it was concluded that the study did not provide evidence that prolonged transportation (with associated prolonged fasting) is more stressful for chicks from young or old breeders, compared to short transportation (with associated short fasting).

> The available evidence suggests that the maximum journey time of 24 hours (if the journey is undertaken in the first 72 hours post hatch) may still be appropriate based on available knowledge of yolk sac reserves and resource utilisation. However, longer journeys do cause greater physiological stress and future research could specifically address this issue to provide sound scientific evidence in support of the current position or to indicate that new guidelines or legislation should be developed.

Feeding / watering intervals (Chicks)

In many transported animals the physiological challenges presented by the thermal conditions are compounded by extended periods without access to food or water. It has long been thought that the one-day old chick may be partially protected from such stresses by the presence of energy and water reserves in the yolk sac. Older studies proposed that yolk stores in the newly hatched chick constitute 18% of total body weight and contain approximately 2g of lipid and 2.5 ml of water. In the absence of excessive thermoregulatory demands, this represents energy (75-80 kJ) and water supplies sufficient for 3 days without further provision of food and water (MacLeod, 1980; Freeman, 1984). More recent studies have indicated that in modern day old chicks high metabolic rate and rapid utilisation of resources in the first 24 hours post-hatch coupled to delays in transit and placement result in poorer performance and health status throughout flock life (Tanaka and Xin, 1997; Xin and Lee, 1997; Hackl and Kaleta, 1997; Viera and Moran, 1999; Bigot et al., 2001). Major causes of in-transit and post-transport mortality and morbidity are dehydration and undernutrition (Xin and Lee, 1997). A suggested strategy to reduce metabolic depletion during extended transport is the exploitation of the reduction in metabolic rate in crated chicks in the dark (Tanaka and Xin, 1997). The quantity and rate of use of metabolic reserves by basal metabolism, however, is clearly not the only factor which will influence chick survival during transportation. The prevailing microenvironment may impose thermoregulatory and metabolic demands upon the chicks which will require the rapid mobilisation and utilisation of lipid or the evaporation of water. Neonatal chicks do not possess fully developed effective homeothermic mechanisms (Lamoreux and Hutt, 1939; Freeman, 1964; Dunnington and Siegel, 1984) and consequently are vulnerable to the detrimental effects of thermal loads and fatigue and dehydration. In the immediate post-hatch chick both body temperature and metabolic rate increase

(Freeman, 1964), however body temperature remains labile during exposure to sub-optimal thermal environments (van der Hel et al., 1991). Thus, if the transportation environments are unduly hot or cold then immaturity of thermoregulatory homeostasis, including inadequacy of lipid mobilisation or efficient evaporative heat loss during thermal polypnea, may result in stressful or life threatening hypothermia or hyperthermia. In addition the accelerated rates of utilisation of energy and water reserves may result in premature depletion. Freeman (1984) has estimated that reserves may be completely exhausted in as little as 8-10 hours at a temperature of 40°C.

Neonatal chicks do not possess a fully developed effective homeothermic mechanism, and consequently are vulnerable to the detrimental effects of thermal loads and fatigue and dehydration, particularly at high temperatures and in conditions of poor ventilation.

Feeding / watering intervals (older birds)

Because birds do not normally have access to food and water in transit they may become hungry and dehydrated. The latter is particularly likely with high ambient temperatures when large amounts of water may be lost through panting. Birds are also deprived of food, and to a degree, water before they are caught and crated. This is to partially empty their guts in the interest of improved hygiene at slaughter. Food deprivation leads to live weight loss, the rate being rather variable (see: Warriss et al., 1999), and after long deprivation, carcass weight loss. It also reduces liver weight and glycogen levels in the liver and some muscles, (Warriss et al., 1988) which could induce feelings of fatigue (Warriss et al., 1993) although transported birds have nevertheless been observed to tend to be more active subsequently (Sherwin et al., 1993).

Because poultry held in crates or drawers cannot be effectively fed and watered during transport, journeys must be considerably shorter than for red meat species. Although marketing times of over 12 hours have been recorded in the UK (Warriss et al., 1990), much shorter times are to be recommended on various grounds. Mortality is increased progressively with longer transport times (Warriss et al., 1992). These authors recorded the number of broilers dead on arrival in a sample of 3.2 million birds transported in 1113 journeys to a poultry processing plant. Journey times ranged up to 9 hours with an overall average time of 3.3 hours. Total time, from the start of loading birds onto the vehicle to the completion of unloading at the processing plant, ranged up to 10 hours with an average of 4.2 hours. The overall mortality for all journeys was 0.194%. However, as journey time (and therefore total time) increased, so did mortality rate. In journeys lasting less than 4 hours the prevalence of dead birds was 0.16% while for longer journeys the incidence was 0.28%. In all journeys longer than 4 hours mortality was therefore on average 80% higher than in all journeys shorter than this.

Birds suffering painful traumatic injuries such as broken bones and dislocations, which are not uncommon, will suffer progressively more in longer journeys. Liver glycogen, which provides a ready source of metabolic fuel in the form of glucose, is very rapidly depleted after food withdrawal. Warriss et al. (1988) found depletion of liver glycogen to negligible levels within 6 hours. Broilers transported 6 hours had only 43% the amount of glycogen in their livers compared with non-transported birds (Warriss et al., 1993). It may be stressed that during lairage glycogen depletion (liver and muscle) will continue and that lairage conditions (season dependent) will impact upon the metabolic status of the post-transport birds (Warriss et al., 1999). Lairage time and conditions should be a key consideration in journey planning and slaughter scheduling.

> Transported birds are vulnerable to dehydration from panting to dissipate heat, and because food and water is withdrawn before transport. Poultry also cannot be fed or watered in transit and thus journey times must be shorter than for other meat species, generally an effective upper journey of limit of 12 hours.

Journey times - Broilers, turkeys and hens

In a survey of records of the transport of 19.3 million broilers killed in four processing plants in the UK Warriss et al. (1990) found an average time from loading to unloading of 3.6 hours, with a maximum of 12.8 hours. Comparable average times for 1.3 million turkeys killed at two plants were 2.2 and 4.5 hours, with maxima for 4.7 and 10.2 hours (Warriss and Brown, 1996). A survey (anonymous 2010) of poultry transport in France based on responses to a questionnaire found journey times for broilers of up to 3 hours, with averages of 1.2 to 1.3 hours depending on whether the birds were standard or Label rouge values confirmed by Chauvin et al 2011) reported journey times in the French broiler industry between 1 hour and 3 .25 hours. Turkeys travelled for up to 4.4 hours with an average of 1.5 hours. Although there seem to be no published data, spent hens are thought to travel very long distances to slaughter in the UK because of the very small number of plants willing to process them. This long transport must be a cause of some considerable concern.

Nijdam et al. (2004) examined the risk factors for carcass bruising and DOA in Dutch broiler production. The mean dead on arrival (DOA) was 0.46%. The mean corrected bruises was 2.20%. Factors associated with corrected bruises percentage were season, moment of transport, and ambient temperature. Factors associated with DOA percentage were ambient temperature, time of transport, catching company, breed, flock size, mean body weight, mean compartment stocking density, transport time, lairage time, and the interaction term “transport time × ambient temperature”. The most important factors that influence DOA percentage, and which can be reduced relatively easily, were compartment stocking density (Odds ration or OR = 1.09 for each additional bird in a compartment), transport time (OR = 1.06 for each additional 15 min), and lairage time (Odds Ratio = 1.03 for each additional 15 min). It was suggested that in particular, reduction of transport and lairage times might have a major influence due to their large variations. It was proposed that reducing or removing these factors will reduce DOA percentage and animal welfare will be improved.

Verecek et al. (2006) analysed DOA data from the Czech broiler industry over a 7 year period up to 2004 where the average mortality or DOA was 0.25%. Journey length had a major effect on DOA the values being 0.15% for journeys under 50 km up to a maximum of 0.86% for journeys over 300 km. The broiler mortality in transit was also influenced by the season of the year. The highest mortality was found in summer months and in winter months. It was reported that long-term trends indicate an increase in mortality of broilers transported to slaughter.

Voslarova et al. (2007a) have reported an analysis of transport mortality or DOA in hens and roosters in the Czech Republic. Over a 7 year period up to 2004 the mean DOA was in the 0.93% ± 0.48 %. DOAs in hens and roosters were influenced by the transport distance. The percentage of dead birds increased from 0.592% ± 0.575% at transport distances up to 50 km to 1.638% ± 0.952% at transport distances up to 300 km. The bird mortality was also influenced by the season of the year. Higher mortality rates were ascertained during the cold months of the year, specifically in October through to April.

A further study by Voslarova et al. (2007b) compared transport mortality rates (DOA) across poultry species for the period 1997-2006 in the Czech Republic. The study analysed data for broilers, hens and cockerels, turkeys, ducks, and geese transported for slaughter. The correlations with journey distances in the categories up to 50 km, from 51 km to 100 km, from 101 km to 200 km, from 201 km to 300 km, and over 300 km were determined. The highest mortality rates occurred in hens and cockerels (1.013%), followed by turkeys (0.272%), broilers (0.253%), ducks (0.103%), and geese (0.056%). Differences among the mortality rates estimated were highly significant ($p < 0.001$). Mortality rates correlated highly with transport distance. The lowest mortality rates were for the shortest transport distances; in broilers (0.154%), turkeys (0.164%), and hens and cockerels (0.595%) for a transport distance up to 50 km; and in ducks (0.069-0.111%) and geese (0.021 - 0.053%) for transport distances up to 300 km. Highest mortality rates in hens and cockerels (1.892%), turkeys (0.341%), and broilers (0.536%) were observed for transport distances over 200 km, while in ducks (0.147%) and geese (0.253%), highest mortality rates were with transport distances exceeding 300 km. The highest mortality rates for all transport distances were in hens and cockerels, followed by turkeys and broilers. The mortality rate in turkeys for a transport distance up to 50 km was significantly higher than that in broilers. The lowest mortality rates were observed in ducks and geese, with a significant difference between them only for transport distances of 51 to 100 km, where the mortality rate in ducks was higher, and over 300 km, where the mortality rate in geese was higher.

Oba et al. (2009) have assessed the impact of journey time and lairage time on DOA and meat quality in transported broiler chickens in Brazil. Journey and lairage times between 30 and 180 minutes were examined. It was reported that both DOA and the incidence of pale, soft, exudative (PSE) meat increased with longer journey times.

Karaman (2009) reported that increasing transport time between 1-3 hours had a significant effect upon broiler weight loss in transit through increasing degrees of transport stress.

Viera et al. (2010) have examined the effects of pre-slaughter lairage time on the welfare and mortality of broilers transported to slaughter over different distances.
Thermal variables (temperature and relative humidity), distance, lairage time and density of birds per cage were included in the analysis. The effects of distance and lairage time were important in the variation of rectal temperature of the animals and on the number of dead birds per vehicle. Two models were developed
(mean and dispersion models), for each response variable to describe the effects of and interactions between lairage time and distance. As the lairage time in the holding area increased, the rectal temperature of the birds was reduced for all the studied distances. In farm-abattoir distances higher than 25 km, mortality was low when lairage time was lower than 1 hour. However, for distances below 25 km, in the same time interval, the number of dead birds was two-fold higher than in the first situation. Lairage time and journey time may exhibit important interactions in the determination of bird welfare in the pre-slaughter period and due consideration of this must be included in journey planning and scheduling.

Chauvin et al. (2011) studied a range of factors that might be related to DOA in broiler chickens in the French industry. The study was described as a descriptive and analytical epidemiological study. The factors influencing the DOA rate included animal characteristics and rearing, catching, transport and lairage conditions.
The average DOA rate was 0.18% (from 0% to 1.4%). Variables found to be associated ($P<0.05$) with the DOA rate in a multivariable negative binomial model were flock cumulative mortality on farm, the catching system (mechanical harvesting being

more of a risk than manual collection), the stocking density in crates (more space allowance being associated with less mortality) and climatic conditions (rain and wind being associated with more DOA). There were no obvious relationships with journey length or journey time but this is explicable by the very narrow range of journey durations / distances reported in that study and the fact that mean journey time was low compared to many other studies.

Yalcin and Guller (2012) studied the effects of transport distance on blood metabolites and breast meat quality of broilers slaughtered at different weights. Transport distance was categorised as short (65 km), medium (115 km) and long (165 km) distance representing 90, 155 and 220 minutes at an average 45 km/h speed, for each slaughter weight. Higher heterophils and heterophil/lymphocyte (H/L) ratios were obtained for broilers transported over a long distance. Long distance transport increased blood albumin, glucose, and triglycerides levels for both body weight categories. It was concluded that the effect of transport distance could not be evaluated independently of slaughter weight. The interaction between transport distance and slaughter weight contributes to pre-slaughter stress and meat quality issues.

Aral et al. (2014) have studied the effects of journey duration on losses (DOA) in the Turkish broiler industry. That study grouped journeys into durations of 0-2 hours, 2-4 hours, 4-6 hours, 6-8 hours, 8-10 hours and greater than 10 hours. Mortality was found to be 0.41% across all durations but the rate rose from 0.29%-0.46% with increasing journey time.

A disturbing trend (negative) in broiler mortality rates in transit (DOA) has been reported by Vecerek et al. (2016). Over a 5 year period overall transport-related mortality of broiler chickens transported for slaughter in the Czech Republic was 0.37%. It ranged from 0.31% to 0.72%, the increase approximately corresponding to increasing transport distances. Statistically highly significant ($p<0.001$) differences were found when comparing transport-related mortality rates in individual seasons of the year. The greatest mortality (0.55%) was associated with transport carried out in winter months whereas the lowest losses (0.30%) were found in chickens transported for slaughter in summer months. However, when considering these findings in the light of previous analyses and publications the study revealed greater transport-related mortality rates in broiler chickens transported for slaughter than expected. The most pronounced increases were found during transport for shorter distances and in winter months. However, an increase was found at all transport distances monitored except for distances exceeding 300 km and all seasons except for summer. Furthermore, a general increasing tendency in chicken losses during the monitored period was found. It was proposed that it is essential to identify the specific factors leading to such high and growing mortality rates and developing practical guidelines to improve the welfare of the birds in transit accordingly.

Caffrey et al. (2017) have characterised the key risk factors for mortality in broiler transportation in Atlantic Canada. Available commercial data were analysed using a multilevel linear model. Most of the variation in the mortality risk occurred at the load level rather than at the producer or barn level. There were significant effects of bird sex, age and weight, catching team, journey duration and holding barn duration on mortality risk. The following environmental risk factors increased mortality risk: cold temperatures during the journey and in the holding barn, low crate stocking density during journeys at cold temperature and increased trailer temperature when in the holding barn. The analyses identified risk factors that can be used to refine management practices to mitigate some of the mortality risk. The climatic conditions in Atlantic Canada were responsible for significant risk factors that affected the mortality risk. Refinements of the management practices such as reduced journey and lairage durations, and increased crate stocking density may represent theoretical strategies for risk reduction but may be of limited practical use.

The effects of journey duration, slaughter age and seasonal factors upon bird weight losses during transport in Turkey have been reported by Arikin et al. (2017). Total transportation losses were compared among the four seasons of the year, two slaughter ages (younger broilers, 31-39 days of age; older broilers 40-46 days of age) and three distance ranges (short, ≤50 km; medium, 51-150 km; and long, ≥151 km).

The data indicate that losses increased with transportation distance ($p<0.05$). Broilers slaughtered at a younger age presented lower total losses than those slaughtered at an older age ($p<0.05$). When seasons were evaluated, the highest total loss was determined in the summer whereas losses in spring and winter were found to be relatively lower. It is proposed that seasonal conditions and journey length should be central considerations in production and journey planning and scheduling.

The effects of journey duration and flock health status upon mortality in transit or DOA in Norway have been investigated by Kittelsen et al. (2017). This study examined flocks with normal and high mortality during transportation. The mean Norwegian broiler DOA for 2015 was 0.10%. The most frequent pathological finding in DOA broilers was lung congestion which was observed in 75.5% of birds. This post-mortem finding was significantly more common in broilers from high-mortality flocks (89.3%) than in broilers from normal-mortality flocks (58%). The following variables had a significantly ($P<0.05$) higher median in the high-mortality flocks: flock size, 1st week mortality, foot pad lesion score, carcass rejection numbers and journey duration. The results indicate that high broiler mortality during transportation to the abattoir may be linked to several steps in the broiler production chain. The results suggest that preventive measures are to be considered in improvement of health and environmental factors during the production period and throughout the journey duration.

The factors associated with pre-slaughter mortality or DOA in turkeys and laying hens in Italy have been characterised by Di Martino et al. (2017). Pre-slaughter transportation may affect poultry welfare and mortality rates. The factors considered and analysed were environmental temperature, travel duration, genetic line, gender, crate type and crate stocking density. The median DOA was 0.14% in turkeys, and 0.38% in hens. In turkeys, travel duration longer than 30 min, temperature higher than 26°C and high in-crate stocking densities were associated with increased DOA. In winter (⩽2°C), high stocking densities did not reduce the mortality risk from cold stress; on the contrary, for stocking densities either near to or just above the maximum density in EC Regulation 1/2005, the DOA risk was greater than for loads with densities of 10 kg/m^2 less than the EC maximum. Male birds and specific genetic lines also showed a higher DOA. In hens, transportation lasting longer than 2 hours and the brown feathered breed were associated with higher DOA. The level of DOA progressively increased with travel duration, remaining constant between 4 and 6 hours and peaking at 8 hours (median: 0.57%). The maximum DOA increase was detected during winter.

The effects of journey distance upon DOA in the Spanish broiler industry and the influences of a number of other environmental, procedural and bird variables have been examined by Villarroel et al. (2018). In addition to transport distance the variables considered included waiting time, maximum and minimum daily temperatures, precipitation and maximum wind speed. The overall level of DOA was 0.187%. The effect of the daily maximum outside temperature on DOA was quadratic with minimum DOA at 21.5ºC. Arrival time to the slaughterhouse and waiting time increased DOA by 0.0044% and 0.0021% for every 60 minute increase, respectively. DOA was higher in males (which were heavier than females), and in the flocks that were previously thinned. An interaction between thinning and bird type was found, so that DOA were higher in previously thinned flocks of male broilers and roaster females. Despite the high incidence of thinning and larger bird weight, the percentage of DOA was comparable to previous studies.

Taken together these data suggest average DOA for broilers of between 0.1-0.60%, a higher mortality in hens than in slaughter birds (0.38-1.0%, although these birds may travel further to slaughter than broilers), and generally lower mortality in other bird species than in chickens: turkeys (0.14-0.27%), ducks (0.10%) and geese (0.056%). The most significant indicators for DOA are journey length, with DOA rising for journeys over 50 km, stocking density and ambient temperature/season. Other contributory factors for mortality are catching practices on farm, breed, flock size, mean body weight, and lairage time.

> Published evidence suggests that based on mortalities for modern broilers journeys of over 4 hours duration impose an increased risk to welfare and survival and product quality. There have been previous recommendations concerning the definition of a maximum journey time to slaughter for meat poultry and this requires further consideration.

Rest periods

Rest periods are impracticable and counterproductive for poultry since, as mentioned above, birds cannot realistically be offered food and water. Neither can they be effectively inspected by Veterinary Authorities because of their close confinement in the transport receptacles. Moreover, with current systems of passively ventilated transport vehicles, the reduction in airflow likely if vehicles stop without unloading the birds is likely to lead to an increase in temperature within certain parts of the load and possibly cause the development of hyperthermia in the birds.

Feeding and watering

As mentioned previously, because birds transported in crates or the drawers of modular systems, it is not practicable to feed and water them. This highlights the importance of short transport times and careful control of overall fasting times before slaughter such that a balance is struck between the requirements of slaughter hygiene and those for animal welfare.

Laying Hens

Weeks et al. (2012) reported a survey of DOA in the UK industry involving the transportation of over 13 million end-of-lay hens. The average mortality (DOA) was 0.27% (median 0.15%). The main risk factors for DOA were identified as slaughter plant, distance travelled and external air temperature, with longer journeys and low external air temperatures increasing the risk. Other highly significant risk factors

(P<0.001) related to the condition of the birds on farm, where an increased risk of DOA was positively associated with poor feather cover, lower body weight, cumulative mortality of the flock and poor health (indicated by a high proportion of the load rejected at the plant for traumatic injury and disease state). However, the data indicate that by taking risk factors into consideration it is possible to transport hens up to 960 km with low losses in temperate conditions.

Ducks

Erisir et al., (2008) report significant physiological stress in ducklings transported for between 4 and 12 hours with longer journeys having a greater impact on physiological biomarkers of stress and body weight.

Zhu et al., (2015) have described "serious stress" in ducks transported to slaughter on journeys of 2 hours duration. However, the assessment was based primarily on biochemical indicators of muscle and oxidative metabolism and all parameters returned to normal after a 2 hour pre-slaughter recovery period.

Losses (DOA) during commercial transportation of ducks in the Czech Republic has been analysed by Voslarova et al., (2016). The mean DOA for duck transport was 0.08% and over 5 year period ranged from 0.06 to 0.09%. The lowest transport-related mortality (0.052%) was found for distances shorter than 50 km. It was significantly (p< 0.001) lower than the mortality rates connected with longer journeys. The greatest mortality rates were found for transport distances of 101–200 km (0.105%). In addition, the season of the year significantly affected transport-related mortality in Pekin ducks. The highest death losses were found in the summer (0.090%). The lowest death losses were found in ducks transported in the autumn and winter (0.069% and 0.072%, respectively). Journey durations and vehicle thermal micro-environments were proposed as the key factors determining DOA and bird welfare during commercial duck transportation.

Handling, Loading and Unloading

The importance of careful handling is evidenced by differences in the amount of bruising in broilers harvested by different catching teams (Taylor and Helbacka, 1968), the implication being that some catchers are less skilled or less considerate than others. Birds should be lifted carefully. Ideally this should be by holding the body. However, it is more usual, if not universal, to catch and lift birds by their legs. Both legs should be used to lift the birds since this reduces the frequency and severity of haemorrhaging in the thigh (Wilson and Brunson, 1968). It also reduces the number of broken bones sustained. Gregory and Wilkins (1992) found that removal of hens from cages holding the birds by two legs compared with a single leg reduced broken bones from about 13% to 5%.

The removal of hens from battery cages is even more difficult since these do not usually allow easy access. It is therefore important that the cage fronts are opened sufficiently and that the birds are removed carefully. Catching hens in “alternative” systems such as percheries is often made difficult by the furniture and structure associated with the perches and nest boxes, and the fact that birds have more opportunity to escape. Both cages and alternative systems should therefore be designed with bird depopulation in mind since easy catching is likely to be less stressful to the birds and result in less physical trauma.

The use of mechanised catching for broilers has some advantages (Berry et al., 1990). Several types of mechanised systems have been proposed but only those that use sweeping mechanisms provided with soft rubber “fingers”, usually mounted on vertically rotating rotors, have been successfully developed commercially. The fingers sweep the birds onto a conveyor belt that transfers them to the transport receptacles. Potential advantages of mechanised systems include reduced labour costs, obviation of human health problems associated with manual catching and improved animal welfare, specifically a reduction in bird stress and trauma. However, in practice it is unclear whether there are improvements in welfare, probably at least in part because the standard of care exercised in manual catching systems, with which the mechanised systems must be compared, varies considerably. There may also be differences between different designs of catching machines.

In a recent rather extensive German trial of a catching machine employing a three-rotor sweeper and conveyor system manufactured in Denmark, 40 manually caught loads (869,738 birds) were compared with 43 machine caught loads (1,112,419 birds) over a period of a year (Knierim and Gocke, 2003). Machine catching significantly reduced the prevalence of fresh bruises, leg and wing bone fractures, and bone dislocations, of all categories studied. The improvement in the number of bruises ranged from 23-31%, the improvement in the number of fractures ranged from 48-70%, and the improvement in the number of dislocations ranged from 20-50 %. The number of birds with one or more injuries was significantly reduced from 4.38% in manually caught birds to 3.07% in machine caught birds.

Mortality (% DOAs) ranged from 0.23-0.69% in manually caught birds and from 0.31-0.76% in machine caught birds when sampled over the four seasons (autumn, winter, spring and summer). Only in spring was mortality significantly different between the catching systems, when it was higher for mechanically caught birds. Overall, mortality in manually caught birds tended ($p = 0.07$) to be lower (0.39%) than in machine caught birds (0.54%).

The authors noted that the prevalence of injuries in mechanically caught birds significantly decreased with greater experience by the catching team in the machine's use; the same was not true for manually caught birds. The implication is that further reductions could be possible in the amount of live bird damage from the figures achieved in the study.

Schneider (2000) apparently studied the same birds as Knierim and Gocke (2003). She found that deaths in the mechanically caught birds were caused by heart failure, fractures, liver rupture, or haematomas in the spleen or kidneys. There were more deaths with faster speeds of the conveyor belt, probably because the higher speeds led to more birds than desirable being put into the transport receptacles. Stocking densities were therefore higher than after manual catching. This led to more DOAs caused by shock and hyperthermia. It was suggested that the increased level of bruising at lower stocking densities was caused by birds losing their balance during transport.

On arrival at the processing plant birds are unloaded into lairage. This is a covered area where they are held until moved to the slaughter line. Warriss et al. (1999) examined the effect of holding broiler chickens in their transport “modules” in lairage for up to 4 hours. The two most important consequences of longer times were that the bird’s deep body temperature increased progressively, with the most rapid rate of increase occurring in the first hour, and that liver glycogen decreased after the first 1 or 2 hours in lairage. The implication of the progressive increase in body temperature is that the birds were unable to thermoregulate adequately to maintain their temperature constant under the conditions prevailing in the lairage. Generally, with longer time, the temperature and relative humidity of the air within the containers in which the birds were held tended to increase. Based on their findings the authors recommended that broilers should ideally be killed immediately on arrival at the plant with a maximum acceptable lairage time of 1 hour. Holding birds for longer would require the development of improved methods of ventilation of the modules.

An interesting variation in the behavioural and physiological responses of different lines of laying hens has been reported by Cheng and Jefferson (2008). The data indicate that there is a genetic basis of variations in chickens in response to transportation stress.

Voslarova et al. (2010) propose that pre-transport handling procedures e.g. catching, crating, and loading may be more stressful for broilers than the transport itself. The same authors (Voslarova et al. 2011) have described short term changes in metabolic and stress markers associated with handling and crating of broilers. The findings may reflect acute handling stress coupled to the effects of feed withdrawal prior to transport.

Sherlock et al. (2012) have described the changes in hepatic gene expression associated with feed withdrawal, catching and transport of broilers. The principal molecular and cellular functions thus affected involved lipid and carbohydrate metabolism with a suppression of mRNA expression for genes involved in lipogenesis, glycolysis and glycogenolysis and an induction of those involved in gluconeogenesis, fatty acid metabolism and ketone synthesis. Stressful events such as feed withdrawal, catching and transport in commercial broiler chickens alter expression of hepatic genes associated with energy metabolism, with exhaustion of stored hepatic and pectoral muscle glycogen.

Jacobs et al. (2017c) have reported one of the few studies on the various stages of pre-slaughter handing and transport in broilers including the effects of catching and crating. The study attempted to identify and quantify the major risks associated with the procedures in relation to bird welfare in the Belgian industry. Animal-based welfare indicators were scored before the start of the pre-slaughter phase as well as after the catching, transport and lairage, and slaughter stages to assess the impact of each stage. The overall pre-slaughter phase resulted in a mean weight decrease of 5.3%, a prevalence of 1.4% in leg bruising, and 3.7% in breast or wing bruising. Wing fractures occurred mainly during the catching stage: Prevalence increased from 0.1% to 1.9% (p = 0.003). A welfare comparison before and after transportation and lairage revealed increased plumage soiling, a significant hypothermia accompanied by huddling and clear indications of “crating discomfort”. Risk factor analyses revealed that carefully choosing the catching crew, minimizing thermal stress, reducing duration of transportation, and worker training represent potentially beneficial strategies.

Birds are caught at depopulation by the body, one or both legs or be mechanical catching machines. Although body capture would be preferable, birds are generally caught by the legs. Machine capture can reduce bruising, bone breakages and dislocations compared to manual capture and improves with experience of using the device, unlike manual capture. Worker training in catching and handling, as well as minimizing thermal stress and reducing transportation time will improve bird welfare.

Holding animals in lairage causes an increase in deep body temperature, and depletion of muscle glycogen. It is therefore recommended that birds are killed immediately on arrival at the slaughterhouse, or within 1 hour.

Newly hatched chicks; Vehicle design

The ultimate determinants of the localised on-board vehicle (chick transporter) micro-environment are the prevailing climatic conditions, the addition of heat and water vapour to the load space from all sources including the bio-load (chicks) and the ventilation rate and distribution. All these issues have been extensively addressed in relation to the transport of broiler chickens at slaughter age (e.g. Hoxey et al., 1996; Kettlewell et al., 2000) but the corresponding characteristics of chick transporters have received less detailed study. Valuable measurements of heat and moisture production of chicks are available for calculation of vehicle ventilation requirements (Tanaka and Xin, 1997a) but only the work of Quinn and Baker (1997) appears to have examined in detail the ventilation characteristics of commercial chick transporters. That work employed full-scale experimental determination of ventilation patterns and the prediction of same by Computational Fluid Dynamics (CFD). The important findings included the observation that the presence of the load of stacked chick boxes had a channelling effect upon the air flow through the load space with significant amounts of air by-passing the chick boxes and being re-circulated. The implications of this ventilation regime for air flow in the chick containers was seen in the temperature distributions with peak temperatures occurring in the front central boxes and cooler air by-passing the load. In addition, cooler air entered from beneath the vehicle in the fully loaded configuration and reduced the flow through the load as well as potentially introducing exhaust fumes in to the load space. It must be concluded that considerably more research must address these issues and that those approaches so successful in optimising mechanical ventilation regimes for vehicles carrying other poultry and red meat species (Kettlewell and Mitchell, 2001; Kettlewell et al., 2001) should be applied in future to chick transporter vehicles.

Donofre et al. (2013) investigated the potential effects of mechanical vibrations typical of live chick transportation on the stress responses of newly hatched chicks. In transport simulations chicks were exposed to two levels of vibration (9.64 and 15.19 ms^{-2}) for two hours. The measured chick response variables included change in bodyweight, respiratory rate, and performance in the first week, compared to control groups (without vibration). Chicks subjected to an acceleration of 15.19 ms^{-2} had increased respiratory rates and it concluded that the vibrations may act as a potential stressor during transport of these birds. In an extension to these studies the vibrational characteristics of chick transport vehicles that might influence bird well being have been determined by Nazareno et al. (2015). An air-conditioned vehicle (container type) carrying a total of 63,000 chicks was used. The vibration levels (ms^{-2}) and shock vibrations were recorded using three tri-axial accelerometers. It was concluded that the worst vibration levels occurred on the poor roads. Most shock vibrations occurred on asphalt roads.

The configuration of chick boxes on transporters has an effect on the microclimate, and therefore there is a need for further research to understand the best design for the transport of newly hatched chicks. Similarly to other species, chicks become stressed by vibration and poor road quality affects chick welfare.

Air transport of chicks

Ever increasing numbers of chicks are transported by air over long distances and may be subject to delays and periods of holding in less than optimal conditions constituting significant welfare concerns. Schlenker and Muller (1997) claim high mortalities occur in air transit due to long periods of inanition and dehydration and that these problems will be significant if the birds are still in transit 48 hours after hatching and no food or fluids are provided. Air journeys are often preceded by long holding periods on the ground and holding periods and road transportation after arriving at the country of destination. This complex journey structure can promote the transportation stresses and lead to increased mortalities. In these circumstances mortalities appear to be closely correlated with journey durations (Xin and Rieger, 1995a, 1995b). Eight journeys were studied involving 13-18 hours flying 27-57 hours of ground operation and thus 42-72 hours of total journey time. The relationships between total transport time (Hr) and Dead on Arrivals (DOA) and Seven Day Mortalities (SDM) were:-

$$\mathbf{DOA\ (\%) = -13.89 + 0.324 \times Hr\ (R^2 = 0.82)}$$

$$\mathbf{SDM\ (\%) = -55.8 + 1.378 \times Hr\ (R^2 = 0.81)}$$

Also it was clear that the influences leading to the high initial mortalities on extended journeys contributed to the longer term losses as SDM was related to DOA in a highly significant manner.

SDM = 3.53 + 4.17 x DOA (R^2 = 0.95)

These problems are exacerbated when thermal conditions within the aircraft hold are poorly controlled on long haul flights. In the same studies a wide range of variations in aircraft hold conditions were observed. Chick container temperatures fell rapidly by up to 7ºC upon departure and increased by up to 10ºC upon touchdown. Stressful elevated temperatures were observed during holding on the aircraft prior to take off and again upon landing. The authors recommended that total journey time should be maintained below 45 hours in order to avoid "excessive mortalities". A further issue associated with aircraft hold conditions is the reduced barometric pressure and the reduction in water vapour density observed in the recycled air. Thus whilst barometric pressure on the ground for the above journeys averaged 100kPa, in flight the value fell to 84kPa which will promote water loss (and dehydration) by altering the gaseous diffusion coefficient (Birchard, 2000; Westerterp et al., 2000). This situation would be exacerbated by low ambient humidity or water vapour density. The design of chick containers and their configuration in stacking has also been questioned (Tanaka and Xin, 1997b). Inadequate passive ventilation flow through the boxes when chicks are held in warehouses prior to flights or during other holding periods in aircraft holds before take off and after landing, quickly resulted in potential heat stress conditions even when external temperatures were only moderately warm. It is difficult to obtain estimations of ventilation rates for commercial aircraft transporting animals but the work of Xin and Rieger (1995b) demonstrated that air exchange rates through the chick containers was 3.67 $m^3h^{-1}kg^{-1}$ during flight and 9.03 m^3hr^{-1} kg^{-1} during ground operations. These values are within the recommended ventilation rates for air transport of chickens. For all long distance transport of chicks it has been recommended that water and feed should be available in transit to reduce mortality and maintain welfare and productivity (Xin and Lee, 1996; Xin, 1997; Tanaka and Xin, 1997a). Water may be provided in the form of commercial hydration gels e.g. Aqua-Jel® or Pacific Oasis® which are simply cut into slices and placed in each container or box. As with road transport vehicles further research is required to characterise the prevailing on-board environments, the nature of the ventilation regimes and the consequences for the birds. Only in this way can strategies for improved conditions and welfare be developed.

Chicks transported by air are exposed to long and complex journeys, with risk of variable temperature and water pressure. This can lead to dehydration and thermal stress, and mortality is closely related to journey duration. Further research is required to address the on-board environment and ventilation in order to improve the welfare of transported chicks.

Space allowance

There are few research publications available relating to space allowance and stocking densities for broilers or hens during transport. Canadian recommendations (Anon, 2001) are that, for growing and adult birds, the maximum density in "cold" weather as found in winter should be 63 kg/m^2. The stocking density in summer should be reduced from this value, although no specific reduction or density is specified. It is not clear whether these recommendations are based on research findings or on practical experience. New Zealand recommendations (Anon, 1994) are that poultry weighing less than 1.6 kg need 175 cm^2/kg, those weighing 1 to 3 kg need 150 cm^2/kg and those weighing 3 to 5 kg need 110 cm^2/kg. It was recommended that these space allowances should be increased during summer, especially if the weather is hot or humid. Again, it is not clear whether these recommendations are based on research findings or on practical experience.

However, if the minimum space required by a bird is defined by the general equation:

$$\text{Area } (m^2) = 0.021 \text{ weight (kg)}^{0.67}$$

then a bird weighing 2.0 kg needs 0.0334m^2, equivalent to a stocking density of 59.9 kg/m^2, and a bird weighing 2.5 kg needs 0.03889m^2, equivalent to a stocking density of 64.4 kg/m^2. The Canadian figure of 63 kg/m^2 thus corresponds reasonably well with maximum acceptable stocking densities predicted by theory, at least for "cold" weather conditions, and for birds weighing between 2 and 2.5 kg. For a bird weighing 1.5 kg the corresponding figures are 0.0275m^2 and 54.4 kg/m^2. The equivalent New Zealand figures are that a bird weighing 2.5 kg needs 0.0375m^2, one weighing 2 kg needs 0.0300 m^2 and one weighing 1.5 kg needs 0.0263 m^2.

The New Zealand recommendations (Anon, 1994) specify minimum container height requirements. For poultry weighing 1 to 4 kg this is 25cm.

As implied by the above recommendations, particularly in hot weather it is important to reduce the stocking density in the crates or module drawers to allow better air circulation and prevent the build up of heat and humidity. This can be illustrated by data from Warriss et al. (1992) relating to the provisions made in one UK plant. Between March and August, when ambient temperatures would have increased considerably, stocking density was reduced progressively from 17.3 to 15.8 birds per transport crate. This was associated with a reduction in mortality from 0.22% to 0.16% despite the higher ambient temperatures probably experienced. The reduction in stocking rate corresponds to a decrease of 8.7% in stocking density.

Delezie et al. (2007) have assessed the extent of transport stress as influenced by crate stocking density by measurement of a range of plasma biomarkers. Plasma hormone as well as metabolites, rectal temperature, and heat shock protein 70mRNA, all indicated the high stress level of transported broilers. Plasma corticosterone concentrations increased as a consequence of the procedure
of transportation and peaked if broilers were crated at high density. It was concluded that transportation at high stocking densities should be avoided to reduce economic losses and stress to broilers. Crating density was proposed as a major determinant of welfare in transported birds.

The European Food Safety Authority has highlighted the lack of scientific evidence supporting recommendations on the height of crates used for poultry transportation (EFSA, 2011). During transport from the farm to the slaughter house birds are often confined in crates with limited space. In a Canadian study, Wichman et al. (2010) investigated how the confinement of male turkeys in crates of three different heights height for 6 hours, affected their welfare through assessments of behaviour and physiological responses. The degree of confinement in the crates had little influence on the physiological measures taken, although there was a large effect on the birds' behaviour. The lowest (40cm) crates impaired the birds' ability to move and change positions, whereas the higher (55cm) crates allowed the birds to stand up and move around almost as much as if kept in free height, even if they were not able to stretch their necks while standing. In a subsequent study Wichman et al. (2012) examined the welfare of male turkeys transported in crates 40cm and 55cm in height. Observations on the birds' behaviour during lairage, carcass damage and meat quality were carried out after four commercial slaughter transport journeys. Birds in 40cm crates panted more and lay down more than birds in 55cm crates during lairage. A large percentage of the carcasses had some damage. Significantly more birds from the 55cm crates had scratches on their backs than birds from the 40cm crates. There was no significant difference in meat quality between birds transported in the two crate heights. Both positive and negative effects of increased crate height were established and there is no evidence from this study that merely increasing crate height improves turkey welfare.

The effects of crate height have been assessed further by Vinco et al. (2016) in a study in which the welfare of birds transported in commercial crates was compared with that of others transported in crates of doubled height. Animal welfare was evaluated through the use of animal based parameters, such as behaviour, physiologic variables, dead on arrivals, and post-mortem lesions observed at slaughter. None of the parameters assessed proved advantages of the higher crates over those currently used. On the other hand, several parameters underlined favourable aspects of current crates toward the modified ones. The proposal that transport crates commercially in use at present should be replaced with crates doubled in height is not supported by improvements in animal welfare. On the contrary, it is suggested that this replacement would have a negative effect on the welfare of broilers during transport.

It is agreed that there is only limited information available on suitable height of transport crates for turkeys Di Martino et al. (2017). That study compared behaviours and physiological indicators of groups of female turkeys confined in either conventional (38.5cm height) or experimental (77cm height) crates during commercial pre-slaughter transportations for 86km. Behaviours of birds differed according to route and road type. Crate height had no significant effect on haemato-biochemical markers. These results suggested that crates enabling a standing position may increase potentially dangerous behaviours. Moreover, busy and curvy routes should be avoided, as they may contribute to increasing the frequency of stress related behaviours.

> There are few scientific studies on stocking density for the transport for broiler chickens. However, a high stocking density increases stress and DOA, particularly in hot weather. Evidence for a welfare benefit of sufficient head height for birds to stand readily is mixed – there is evidence for damaging behaviours if birds can stand, and of stress responses and panting in lower crates.

Thermal Conditions and Ventilation

Newly Hatched Chicks

Thermal stress may be the major source of welfare compromise during the transportation of newly hatched chicks. Whilst commercial breeders and producers have long recognised the necessity to maintain an appropriate thermal environment for chicks in transit (Tamlyn and Starr, 1987; Freij, 1988; Laughlin, 1989; van der Hel and Henken, 1990; Qureshi, 1991; van der Hel et al, 1991) the conditions employed have been largely defined by empirical means and have been based upon minimisation of mortality rates during and following transport and efficient productivity during the subsequent rapid growth phase. In current practice the recommended temperature for chick transport is 24-26ºC (Ross Breeders, 1996; Meijerhof, 1997; Weeks and Nichol, 2000) although only the breeder companies advice includes a recommendation of controlled humidity (75% at 24ºC).

It may therefore be proposed that in order to simultaneously optimise survival, productivity and welfare of the newly hatched chick in transit an effective strategy would be to match the thermal characteristics of the microenvironment to the biological requirements of the birds. Some previous studies have attempted to define thermoneutral or optimal environments for neonatal chicks on the basis of metabolic heat production and body temperature responses (Misson, 1976; Henken et al., 1989; Gates et al., 1989; van der Hel et al., 1991). Generally these studies did not measure other indicators of homeostatic effort which might better define the physiological impact of the thermal micro-environment. More recently Xin and Harmon (1996) examined the effects of a range of temperatures and humidities (20-35ºC and 40-17%) upon day old chicks by measuring metabolic rate and mortality. They concluded that optimum or thermoneutral conditions occurred between 30-32ºC. Xin (1997) has also reported that chicks held at a constant 29ºC do not exhibit a different mortality or body weight loss compared to birds exposed to as much as a 16ºC cycling temperature around the same mean temperature. Studies in the present author's laboratory, the subject of a preliminary report (Mitchell et al., 1996) have employed physiological stress modelling, measurement of metabolic rate and the concept of AET (Mitchell and Kettlewell, 1998; Mitchell et al., 2001a; Mitchell et al., 2001b) to determine optimum transport thermal environments for one day old chicks. All measurements were performed on chicks in commercial transport containers in calorimeter chambers housed in controlled climate rooms. Temperatures of 20-35ºC accompanied by relative humidities (RH) of 50-65% and durations of exposure from 3-12 hours were employed. Metabolic heat productions ranged from 7.8±0.3 to 8.7±0.9 Wkg^{-1} in close agreement with previously published values (van der Hel et al., 1991; Tanaka and Xin, 1997a). On the basis of minimal change in body temperature and minimal alterations in basal metabolic rate, hydration state, electrolyte balance, body weight loss and plasma metabolite concentrations an optimal temperature-humidity range of 24.5-25.0ºC and 63-60% RH for the transport of chicks at commercial stocking density was identified. It was emphasised that these physiologically ideal conditions are very similar to those currently employed by commercial breeders and producers. The studies also provided evidence that if the thermal micro-environment is appropriately controlled then journey durations of at least 12 hours are wholly acceptable. It is concluded that both productivity and welfare of day old chicks in transit can be maintained by careful regulation of the temperature and water vapour density to these prescribed limits inside the transport containers. Further work on behavioural identification of the preferred thermal conditions for chicks in commercial transport simulations will provide further refinement and support to these strategies.

Thermoregulatory responses of newly hatched chicks to cold and heat challenges compared to a “thermoneutral” environment have been studied in transport simulations by Viera et al. (2016). Chicks were exposed to the three thermal conditions (cold (21°C), thermoneutral (35°C) and Hot (38°C)), for 1 hour in commercial transport containers in an environmental chamber. The boxes were stacked as in commercial practice in order that any effect of box placement might be determined. Body weight, respiratory frequency, mean surface and cloacal temperature were monitored. The box placement had a negligible effect on the thermal comfort of birds. The mean surface and cloacal temperature responses were markedly affected by the cold treatment. It was suggested that longer simulated journey durations the higher temperatures might also affected the chicks' thermoregulatory responses.

> Evidence from a minimal change in body temperature and minimal alterations in basal metabolic rate, hydration state, electrolyte balance, body weight loss and plasma metabolite concentrations an optimal temperature-humidity range of 24.5-25.0ºC and 63-60% RH for the transport of chicks at commercial stocking density is recommended. If the thermal micro-environment is appropriately controlled then journey durations of at least 12 hours are acceptable. Both productivity and welfare of day old chicks in transit can be maintained by careful regulation of the temperature and water vapour density to these prescribed limits inside the transport containers.

Chick Mortality

There appear to be no accurate scientifically based surveys yielding estimates of mortality during road transportation of one day old chicks. Commercial practice often involves calculation of three day and seven or eight day mortality reasoning that these values (total losses from birds transported) integrate the overall effects of the transport process and placement. On this basis, mortalities of 1.0-1.7% have been reported (Tanaka and Xin, 1997). There are no studies correlating such losses with road transport conditions and events.

Broilers, Turkeys and Hens

Both environmental temperature and humidity (water vapour density) are important factors affecting welfare. An important method of losing heat in poultry at high temperatures is by evaporative cooling from the respiratory tract. The birds pant to facilitate this, but at high humidity levels evaporative mechanisms become less effective or ineffective. Because of the way the crates or module drawers are stacked on the transport vehicle airflow is severely restricted. A major problem is therefore dissipation of heat generated by birds in the centre of the load. Conversely, birds on the outside of the load may be exposed to the elements. To protect them from becoming cold and wet, in inclement weather, and especially in winter, side curtains are used. However, by further restricting airflow, these may compromise the welfare of the birds in the centre of the load even more. Without side curtains, ventilation of the load is probably just sufficient when the vehicle is moving but becomes problematic when it is stationary. However, when stationary, lack of ventilation in vehicles fitted with side curtains may lead to hyperthermia in many of the birds. Long periods of panting may also cause dehydration. Low ambient temperatures appear generally to be less important as a welfare concern. However, birds can become hypothermic, especially if they are poorly feathered, wet or dirty, and are subject to the effects of wind chill (Weeks and Nicol, 2000). The importance of wet plumage in increasing body heat loss, particularly during simultaneous exposure to both low temperatures and significant air movements (air velocities of 0.5 ms^{-1} or greater), was demonstrated by Mitchell et al. (1997).

Three-dimensional thermal mapping on many journeys on commercial broiler transport vehicles has revealed that distributions of both temperature and humidity (water vapour density) are heterogeneous within the transport space (Kettlewell and Mitchell, 1993a; Kettlewell and Mitchell, 1993b; Mitchell and Kettlewell, 1998). There are substantial lifts in both variables over ambient conditions in parts of the vehicle. It is apparent that a heterogeneous distribution of heat loads exists with a gradient essentially from front to rear of the vehicle resulting in the existence of a "thermal core" towards the upper front central area of the vehicle. On typical transport vehicles temperature lifts of 10-20°C in the thermal core may be encountered in closed vehicle configurations. Thermal core temperatures of 25-26°C accompanied by water vapour densities of 5-17 gm^{-3} may be observed regularly on commercial transporters in the

UK during winter transport when external temperatures may be 5-8°C. On such vehicles an 18°C gradient between thermal core and air inlet will exist with a parallel humidity gradient. Thus, the complex nature of the thermal micro-environment on broiler vehicles may result in a risk of severe heat stress in relatively mild weather conditions. Core temperatures of >30°C and vapour densities >20gm^{-3} have been reported in the UK (Kettlewell and Mitchell, 1993).

More recent studies (Knezacek et al., 2000) have further demonstrated the complexity of the "on-board" thermal micro-environment employing thermal mapping on commercial vehicles under extreme cold conditions. A 60°C temperature lift was reported in one container in a broiler vehicle operating with minimal passive ventilation with an external temperature of -28°C in central Canada. The resulting thermal core temperature of 32°C would have resulted in a degree of “paradoxical heat stress” under extremely cold external weather conditions. Clearly the issues of elevated external temperatures are even more important in countries whose climate is sub-tropical or tropical including those European broiler producers bordering the Mediterranean.

The effects of exposure to high thermal loads in transport containers include profound heat stress and increased mortality and thus major reductions in bird welfare. In production terms there are other important influences. For example heat stress will induced a marked elevation of evaporative heat loss and thus body weight loss (Carlisle et al., 2002). This study included three separate but related experiments and quantified the components of water loss from broiler chickens (2 kg body weight) under a range of thermal environments. In the first, respiratory evaporative water loss was estimated gravimetrically for individual broiler chickens over a range of environmental temperatures from 24-36˚C. In the second, total weight loss was estimated in groups of broilers in commercial transport crates over a similar range of micro-environments. In the final phase, weight change and evaporative water losses of broilers on a commercial transport journey were measured by means of pre and post-journey weighing of the load and determination of inlet and outlet water vapour density on a mechanically ventilated vehicle throughout the journey. Respiratory evaporative water loss increased from 0.77±0.19 g kg^{-1} hr^{-1} at 24ºC to 4.3 g kg^{-1} hr^{-1} at 36ºC ($p<0.001$) in individual birds which would equate to weight losses of 30-168 kg on a typical UK broiler transporter carrying 6500 birds on a 3 hour journey. Measurements of total weight of broilers over a range of temperatures from 20-30ºC on similar simulated journeys indicate losses of 0.87-2.2 g kg^{-1} hr^{-1} ($p<0.001$) which would result in weight reductions at the factory of 34-86 kg per load. Subsequent studies on commercial vehicles revealed actual weight losses of 4.6-6.6 g kg^{-1} hr^{-1} (mean 73 kg per load) under varying thermoneutral conditions chiefly attributable to the measured water vapour heat exchange.

Finally it should be noted that the thermal environment encountered by the birds in transit and the effects thereof may be further compounded by additional holding of the birds at the processing plant prior to slaughter. Studies have demonstrated that lairage or holding micro-environments may be poorly controlled (Quinn et al., 1998) and in consequence hyperthermia or heat stress may occur during this period resulting in acid-base balance disturbances muscle damage and further reductions in bird welfare (Hunter et al., 1998) and depletion of liver glycogen and meat quality alterations (Warriss et al., 1999). Particular attention, therefore, must be paid to the transport and holding thermal micro-environments and the thermal loads imposed upon the birds including both dry bulb temperature and humidity. The consequences of elevated thermal loads for bird welfare and productivity are profound.

> Birds pant to reduce temperature by evaporation from the respiratory tract. However, this is ineffective at high humidity and with poor air flow and ventilation. Thus, birds in the centre of a load are at risk of hyperthermia and dehydration, whereas birds on the outside of a load may become cold and wet. Even on relatively cool days in the UK, localised temperatures in parts of transporters can be 25-26☐C. Core temperatures of >30°C and water vapour densities >20gm^{-3} have been reported in the UK. As air flow and evaporative heat loss is improved with vehicle movements, the longer a vehicle is stationary the greater the risk of heat stress and mortality in transported birds.

Factors determining the thermal micro-environment of poultry transporters

The internal thermal micro-environment in the transport containers is the product of the inlet air temperature and humidity, airflow rate and the heat and moisture production of the birds (Mitchell et al., 2000). It may be suggested that the passive ventilation regimes of most commercial broiler transport vehicles result in low ventilation flow rates and heterogeneous distribution of airflow within the bio-load. Studies have characterised the pressure profiles over the surface of, and within, commercial broiler vehicles (Baker et al., 1996, Dalley et al., 1996, Hoxey et al., 1996). It is these pressures, which drive passive ventilation within the vehicle. A central feature is the tendency for air to move in the same direction as the motion of the vehicle, thus, air tends to enter at the rear and move forward over the birds exiting towards the front. This pattern, of course, accounts for the distribution of temperatures and humidities observed on commercial vehicles, the existence of the "thermal core", the ingress of water spray and bird wetting and the pattern of DOAs and thermal stress found within the load (Hunter et al., 1997; Hunter et al., 2001; Mitchell et al., 1997; Mitchell et al., 1998). The importance of airflow direction and pattern has been emphasized by Mitchell and Kettlewell (2002) who reported work demonstrating temperature distributions at the rear (air inlet) of a passively ventilated, closed sided vehicle on a winter's day. It was apparent that cold air (at velocities of up to 1.2 ms^{-1}) can penetrate the bio-load by up to 1.7m chilling birds in these locations and causing profound cold stress if accompanied by wetting (Mitchell et al., 1997; Hunter et al., 2001). When vehicles are stationary there is no external force driving the ventilation and heat and moisture removal is dependent upon free convection. In this situation problems of heat stress may be markedly exacerbated even on open or semi-open vehicles particularly in hot and humid weather conditions. Whilst the heterogeneity of the thermal micro-environment is less on moving open-sided vehicles, gradients of temperature and humidity still exist. On curtain or closed-sided vehicles the problems of elevated thermal loads and localised cold stress zones can be exacerbated. It is clear that the problems associated with thermal micro-environments are primarily a consequence of the inadequacy and poor distribution of the ventilation flow through the bio-load. Any practical solution to these problems must involve modification and improvement of the ventilation regime.

The aerodynamic basis for understanding the heterogeneous distributions of thermal loads in broiler vehicles has been extensively characterised and described (Hoxey et al., 1996a; Hoxey et al., 1996b; Hoxey et al., 1996c; Mitchell and Kettlewell, 1998; Kettlewell and Mitchell, 2005). That work has provided the basis for the design of improved passive ventilation and mechanical ventilation systems through application of the knowledge of pressure profiles over moving vehicles and airflow through vehicles and loads.

Kettlewell et al., (2000) report average metabolic heat productions on board commercial vehicles for broiler birds at slaughter weight of 4-8Wkg^{-1} or around 10-15W per bird. Based on these studies, mechanical ventilation rates of 0.3m^3s^{-1} $tonne^{-1}$ were recommended for broiler transport vehicles to minimise the risk of heat stress.

A number of modifications to existing passively ventilated vehicles may be made in order to improve air low through the load space, however the success of these strategies is limited particularly in the face of the hostile climatic conditions encountered in many major broiler producing regions. If current transport numbers per vehicle are to be maintained to ensure economic efficiency then forced or mechanical ventilation may be the only feasible option. In order to define the specifications of such a system it is necessary to determine three factors:

(1) The ranges and limits for temperature and humidity within the transport containers and the optimum thermal environment for transport.

(2) The acceptable temperature and humidity “lifts” above ambient for a range of external conditions.

(3) The heat and moisture loads for dissipation by the ventilation system.

Physiological response modelling has provided the data necessary for factors 1 and 2. Total heat and moisture productions of slaughter weight broiler chickens have been measured in a unique study in which a broiler transport vehicle was instrumented to function as a “direct calorimeter” (Mitchell et al., 1998b; Kettlewell et al., 2000;

Kettlewell et al., 2001a). The steady state total heat and moisture production of broilers were measured on a fan ventilated commercial transporter. Temperature and water vapour densities were accurately determined at defined inlets and outlets on an otherwise sealed vehicle and sensible and latent heat losses calculated from precisely calibrated fan throughput. Measurements were made over a 2 hour period on each of 6 days. The lorry carried birds of 1.75±0.06kg body weight. Ambient temperature (T_e) during the experiments ranged from 9-17°C. Two fan flow rates (2.8 and 4.9 m^3s^{-1}) were employed. Mean total heat production on the lorry was 26.1±3.0 kW which could be partitioned into 63% sensible heat and 37% latent heat components. This value represents 9.5±1.0W per bird. In parallel transport simulation laboratory studies using similar birds (T_e = 20°C) metabolic heat production determined by indirect calorimetry was 8.7±0.5W. This value is in close agreement with that determined in the “whole vehicle direct calorimeter” and with previously published total heat productions for broiler birds (Xin et al, 1996).

On the vehicle, water loss was 1.43mg per bird $^{-1}s^{-1}$ and it may thus be calculated that to maintain a specified temperature lift within the transport container the ventilation system must be capable of dissipating loads of at least 5.41Wkg^{-1} and 0.82$mg.kg^{-1}s^{-1}$. In practice, removal of larger heat and water vapour loads may be required. Thermoneutral water vapour productions of broilers as high as 1.8mg kg^{-1} s^{-1} (Xin et al., 1996) have been reported. This must be considered in the calculation of water vapour removal targets and rates. Deep body temperature measurements in broilers at the lorry air inlets and outlets indicated a slight cooling of the birds at both of the ventilation rates employed (-0.41±0.34°C) suggesting at least adequate removal of heat and water vapour loads. It has thus been possible to calculate the ventilation flow rates required for operation in specified external environments from the following relationship:

$$\mathbf{VFR = TMHP / C_p \times \Delta T}$$

Where VFR = Flow rate (m^3s^{-1})

TMHP = Total metabolic heat production (Js^{-1})

C_p = Specific heat capacity of air (1226 $Jm^{-3}°C^{-1}$)

ΔT = Acceptable rise in air temperature (°C)

On the basis of these findings it is proposed that the effective ventilation rate for vehicles in this configuration, fully loaded and operating at environmental temperatures of up to 20°C should be $0.6m^3s^{-1}$ per tonne liveweight (Kettlewell et al., 2001a). Several fans should be installed on the vehicle giving a maximum ventilation rate which will exceed this value. To achieve maximum fan efficiency they should be used to extract air at sites of low pressure where air will naturally tend to leave the vehicle (Hoxey et al., 1996; Baker et al., 1996; Dalley et al., 1996). Fans are available which will achieve this and in practice much higher rates may be required in hot weather. It must be emphasized that removal of water vapour by the ventilation flow is of paramount importance in controlling the internal thermal micro-environment of the poultry vehicle and it is therefore essential to calculate or measure both heat and moisture production of birds over a wide range of thermal conditions. These specifications have provided the basis for the design and development of fan ventilated commercial broiler transport vehicles (in collaboration with a commercial coachbuilder) in the UK (Kettlewell and Mitchell 2001a; Kettlewell and Mitchell 2001a; Kettlewell et al., 2001a; Kettlewell et al., 2001b). The control strategy for the ventilation rate is based upon the physiological response models and measurements of inlet and outlet air temperatures. These vehicles are now operating successfully in commercial practice.

Weeks et al. (1997) investigated and compared vehicle designs for the transportation of poultry. The studies employed an artificial chicken device which allowed quantification of sensible heat loss. The devices were placed in specific locations on commercial poultry transport vehicles using different designs and ventilation systems (passive and mechanical). Data collected in this way were employed to derive general equations to predict H and temperature lift for each vehicle. From these, air movement, V, within the crates was calculated together with predicted sensible heat loss at ambient temperatures to compare the thermal comfort of the vehicles. All naturally-ventilated vehicles were over-ventilated in motion, with mean air velocities ranging from 0.9 to 2.4 m/s within the crate, and maximum ventilation rates of 6.0 m/s resulting in negligible temperature lift above ambient. Poorly-feathered hens were, consequently, extremely cold-stressed in winter. When stationary, vehicles with a central passage that enabled the 'stack effect' to operate were thermally comfortable provided the ventilation rate was kept low. These authors made recommendations for air velocities and volume based ventilation rates for commercial transport of poultry. In this study the mechanically (fan) ventilated vehicles had a similar range of H (sensible heat exchange) whether stationary or in motion. The mean air velocity (V) of 1 to 2 m/s of bird-warmed air maintained satisfactory thermal conditions most of the time. For current designs of poultry vehicle stocked at commercial rates, V should normally be between 0.3 and 1.0 m/s; air temperature near pullets or broilers should be 10.15°C and near poorly-feathered hens 22-28°C. Suitable ventilation rates are likely to be in the range 100 to 600 m3 per hour. It is strongly recommended that appropriate temperature monitoring systems be fitted on all vehicles.

Spurio et al., (2016) have examined a modified truck / trailer / transport container design involving the fitting of flaps to control air flow and have tested the efficacy of this design with and without wetting of the birds / load prior to short distance transport under hot conditions in Brazil. The effects of the new systems were assessed on the basis of impacts on DOA and on meat quality issues specifically the incidence of PSE meat. While there was no difference in the DOA index ($p \geq 0.05$), the prototype truck caused a reduction ($p<0.05$) in the occurrence of PSE meat by 66.3% and 49.6% with and without wetting, respectively. It is proposed that the new design represents a low-cost solution for transporting chickens that yields better animal welfare conditions and improves meat quality.

Petracci et al., (2006) considered the DOA rates for broilers, turkeys and spent laying hens in the Italian poultry industry and reported seasonal effect associated with thermal stress. Thus, the overall average incidence of DOA was found to be 0.35, 0.38, and 1.22% in broilers, turkeys, and spent hens, respectively. The season significantly ($p \leq 0.01$) influenced the mortality of all considered poultry categories, with higher incidences being observed during the summer (0.47, 0.52, and 1.62% for broilers, turkeys, and spent layers, respectively).

High ambient temperatures and truck loading density were identified as the key factors in high mortalities (DOA) in warm weather transport in Manitoba, Canada (Whiting et al., 2007)

Simoes et al., (2009) linked the thermal micro-climate on Brazilian broiler vehicles to stress meat quality problems and advocated wetting of birds prior to hot weather transport to reduce stress and detrimental consequences. Silva et al. (2011) also recommended showering of broilers with cold water after loading and before transport under hot conditions to reduce DOA from around 0.22% to 0.14%.

Voslarova et al. (2010) emphasise the impact of seasons of the year and thermal challenge, asserting that low ambient temperatures in winter represents a more stressful event than transport during fall and summer. Vosmerova et al. (2010) assessed stress in transported broilers using biomarkers including plasma corticosterone and concluded that transport stress associated with thermal challenge was greater at temperatures between -5 and 5°C than at higher temperatures. The authors suggest that cold stress represents a significant risk to bird welfare during winter transport in Europe.

Chauvin et al. (2010) reported that wind and rain were key determinants of DOA during broiler transport but failed to link these relationships to body temperature or thermal stress indices or load locations.

Knezacek et al. (2010) characterised the thermal micro-environments on Canadian broiler transport vehicles in winter under extreme cold stress conditions. Deep body temperature was employed to determine the effects of the micro climates and the location within the load. Temperature heterogeneity was found among modules on all loads with average crate temperatures ranging from 0.7 to 30.7°C at external ambient temperatures between -7.0 and -28.2°C. Wet birds, condensation and frost provided evidence for moisture accumulation during transportation. Body temperature recordings indicated the potential for the development of both hypothermia and hyperthermia, showing that cold stress can occur near air inlets and heat stress in poorly ventilated areas. Passive ventilation inside trailers resulted in crate temperatures 17.7 to 55.2°C above outside temperature. Mortality ranged from 0.7 to 1.4%. The study confirmed the hypothesis that heterogeneous distributions of airflow in commercial broiler loads in transit results in undesirable temperate and humidity conditions for some birds.

Strawford et al. (2011) using transport simulation examined the effects of low temperatures (-5 to -15°C in a controlled air stream) on thermoregulation and behaviour. Exposure to temperatures below -5°C induced hypothermia but in dry fit birds' behavioural thermoregulation minimised the detrimental effects and recovery was possible on removal from the challenge. It must be stressed that recovery alone does not imply acceptable welfare status during the challenge and that low temperature exposure of this kind must be regarded as potentially very stressful.

Other studies under commercial transport conditions in Canada (Burlinguetta et al. 2012) characterised further the distribution of thermal loads within broiler vehicles. Temperature and humidity levels in double-trailer broiler vehicles were examined for a range of ambient temperatures (-24 to 11°C). During warmer ambient conditions (10°C) with roof vents and side curtains open the on-board temperature range was narrow (10.3 to 16.8°C). Closure of vents and curtains in colder weather resulted in increasingly variable and more extreme internal thermal conditions, with the development of distinct "thermal cores". At an ambient temperature of -22.2°C trailer temperatures ranged from -20.7 to 21.8°C with an estimated 58.6% of the load volume being exposed to temperatures below 0.8°C. In addition, the trailer humidity ratio rose by 14.0 g kg^{-1} above ambient and conditions approached saturation (RH 80%) in 55.2% of the load volume. It was proposed that these results support the need to find a means to remove moisture and redistribute heat on broiler trailers during cold ambient conditions.

Viera et al. (2011a) have proposed that DOA may be reduced if birds are subjected to controlled environment lairage post-transport following transportation under thermally challenging conditions. Whilst this may allow some recovery prior to slaughter and may have a positive impact on losses and meat quality the welfare issues may be more complex. High quality lairage should be coupled to good environmental control during the transportation phase to ensure optimum welfare of birds in transit to slaughter. The thermal characteristics of UK broiler lairages were described previously and recommendations made for improved environmental control strategies (Quinn et al. 1998). In other Brazilian studies Viera et al. (2011b) have defined temperature ranges that pose increasing risk to welfare and survival in transported broilers. Thus, temperatures are defined as high (22°C), critical (25-28°C) and lethal (>29°C). The authors propose that climate controlled lairage may reduce the actual DOA in all categories but that substantial losses can still be expected in the critical and lethal external temperature conditions. It was emphasised that lairage time is a key determinant of survival after hot weather transport.

Do Nacimento et al. (2011) have recommended adoption of thermal comfort indices e.g. thermal comfort fuzzy index (TCFI) to ensure inclusion of the factors other than dry bulb temperature when determining the risk to welfare posed by thermal challenge e.g. during transport. Fihlo et al. (2014) have employed an integrated temperature-humidity index (Enthalpy Comfort Index – ECI) to assess the risk of thermal stress and losses in open broiler vehicles under Brazilian transport conditions. The study concluded that the central and rear areas of the load were most susceptible to risk of heat stress and that the risks were high in afternoon transport than in morning or evenings.

Levels of mortality in transit in end-of-lay hens in the UK were examined by Weeks et al. (2012). The average mortality for end of lay hens dead on arrival (DOA) was 0.27% (median 0.15%). A statistical model of the data indicated the main risk factors for DOA to be slaughter plant, distance travelled and external air temperature, with longer journeys and low external air temperatures increasing the risk. Other highly significant risk factors ($p<0.001$) related to the condition of the birds on farm, where an increased risk of DOA was positively associated with poor feather cover, lower body weight, cumulative mortality of the flock and poor health (indicated by a high proportion of the load rejected at the plant for traumatic injury and disease state).

Richards et al. (2014) have characterised the temperatures and humidity conditions in transport crates on journeys carrying spent laying hens to slaughter in the UK. 24 commercial journeys were examined with an ambient temperature range between -0.2 and 29.1°C. Mathematical models revealed significant differences in predicted drawer temperature depending on their location and the outside environmental temperature. Higher predicted temperatures were found in the uppermost drawers of the top modules at the front of the lorry, and lower temperatures in drawers on the outer sides of modules and in those drawers in modules next to the back of the lorry in both the upper and lower modules during transport. End-of-lay hens would appear to be exposed to a greater risk of cold stress rather than heat stress in the UK. The authors suggest that inspection of birds during transport, or upon arrival, should be directed to the bottom and side drawers of a load when looking for cold stress, and the top row of drawers (centre) of the top modules when looking for heat stress. The frequency of such inspections should increase at times of high ambient temperature while the birds are being held in lairages. Adjusting the numbers of birds loaded per drawer according to bird condition and weather appears to be an effective mitigation strategy which is already in use commercially.

Minka and Ayo (2016) have described hypothermia induced by night time transport of pullets relating to position on the vehicle (i.e. peripheral locations with higher air flow presenting a greater risk than central load locations). The study employed enthalpy as a thermal comfort index and it may be suggested based on colonic temperature responses of the birds that specific enthalpy values in the transport containers should be maintained above 85 kJ. kg^{-1} in order to minimise the risk of cold stress for these birds.

Jiang et al. (2016 a and b) have proposed that for hot weather transport a regime involving immediate post-transport showering (5 minutes) and forced ventilation (5 minutes) relieves transport stress and reduces the risks to welfare and product quality.

Arikan et al. (2017) found that DOAs during commercial broiler transport were higher in the summer months compared to winter or spring and were associated with higher temperatures in transit.

The effects of season and the thermal environment upon DOA rate in turkeys during transportation in the Czech Republic have been carried out by Machovcova et al. (2017). Overall mortality among turkeys transported for slaughter was 0.147%. The lowest mortality (0.023%) was found in turkeys transported for distances up to 50 km; longer distances were associated with increasing death rates, with the highest losses (0.543%) recorded for distances from 201 to 300 km. Differences were also found when comparing transport-related mortality rates according to the season of the year. The highest mortality (0.228%) was associated with transport carried out in summer, whereas the lowest death rates were found in turkeys transported for slaughter in winter (0.105%) and autumn (0.113%). The ambient temperatures associated with the highest death rates were 14 to 21°C. It was proposed that heat stress is a major factor in the bird mortality in transit. However, low ambient temperatures (below -2°C) also increase transport-related mortality. It was suggested that the lengths of journeys in accordance with prevailing climatic conditions may lead to a reduction in DOA.

Caffrey et al. (2017) identified factors affecting mortality risk (% DOA) during transportation of broilers to the slaughter plant in Atlantic Canada. Available data were analysed using a multilevel linear model. Environmental risk factors increasing mortality risk were cold temperatures during the journey and in lairage, low crate stocking density during journeys at cold temperature and increased trailer temperature when in the lairage. DOAs could be attributed to both hypothermia and hyperthermia. Potential strategies for reduction of these thermal environment induced problems were presented such as reduced journey and lairage durations and increased stocking densities but may lack practical applications or feasibility.

In the extreme ranges of ambient temperatures found in Atlantic Canada a major risk for increased mortality in transit or DOA is thermal stress (Caffrey et al. 2017).

Hypothermia is associated with a significant increase in DOA at ambient temperatures below -4°C with rapidly increasing losses down to a temperature of -32°C. The study suggested that modifications to existing vehicle passive ventilation systems and practices would not afford effective strategies to maintain welfare or reduce losses at extreme low temperatures. It proposed that mechanical ventilation and/or climate control may offer the only viable strategy in the future. The design of future ventilation systems for broiler vehicles may be best based upon fluid dynamic modelling as applied to broiler house ventilation systems (Rojano et al. 2015).

Jacobs et al. (2017b) examined the risk factors and welfare indicators associated with DOAs in broilers during commercial transportation to slaughter. In relation to the thermal environment they concluded that DOA% may be positively associated with a number of welfare indicators including plumage cleanliness, body temperature, panting and numbers of supine birds and indicators of thermal stress. It was proposed that DOA% could be used as a first and quick screening for pre-slaughter broiler welfare impairment, with the aim of identifying commercially transported flocks whose welfare is most at risk.

Carvahlo et al. (2018) have mapped the thermal micro-climate on turkey vehicles / container systems during transport to slaughter in Brazil. The study also examined the effects of showering the birds and containers with water prior to transport. The findings indicate that for birds transported for 95 minutes under hot-humid conditions there is a “thermal core” at the lower middle and rear truck regions. Showering of the birds was beneficial in terms of outcomes such as meat quality and DOA even in the most vulnerable load locations.

Vermette et al. (2017) have examined the effects of heat challenge during simulated transport in turkeys. Birds were exposed to 20°C control conditions or heat stress induced at 35°C at 2 different relative humidity values. There was a marked difference in response between male and female birds. Males became very quickly distressed in the high temperature treatment and exhibited an extreme hyperthermia. The females also experienced a less severe hyperthermia accompanied by elevated H:L ratios and subsequent meat quality issues. This work does not provide any insight in to temperature limits for transport of turkeys in relation to bird welfare as the treatments employed were extreme and the outcomes predictable.

Henriksen et al (2018)have demonstrated that exposure of 12 week old turkeys to a temperature of -18°C for up to 8 hours under simulated transport conditions resulted in hypothermia compared to control birds and altered behaviours indicative of cold stress. Larger male birds exhibited less change than their female counterparts. Again only limited conclusions can be drawn concerning the effects of transport in crate thermal conditions on turkey welfare in transit as the challenges were extreme.

The impact of external temperature conditions (range 7.6 – 40.1°C) on DOA in transported broilers in Spain has been described by Villarroel et al. (2018). Maximum temperature on the day of transport had a significant effect upon mortality with higher temperatures being associated with increased mortality and the ambient temperature associated with minimum DOA being 21.5°C.

A range of studies confirm the heterogeneity of thermal loads on trasnporters under different ambient temperatures (up to 40 degree differences between different locations have been recorded). It is thus possible for birds to suffer hyperthermia and hypothermia at different locations in the same truck. Modelling studies suggest that mechanical ventilation can provide a solution to these issues and thus this and temperature monitoring is strgonly recommended for all poultry transport vehicles.

Transport Practices

Outcomes, welfare measures etc.

Mitchell et al. (1992) reported physiological and haematological biomarkers that may be employed to study the impacts of commercial broiler transportation and that facilitate the quantification and modelling of transport stress in poultry.

The use of heterophil lymphocyte ratio and tonic immobility to assess the extent of transport stress and the effects of ascorbic acid supplementation broilers has been described by Zulkifli et al. (2000 a and b)

Zhang et al. (2010) reported that transport of broilers for up to 3 hours accelerates muscle energy metabolism and lipid peroxidation. Induction of oxidative stress was assessed by measurement of superoxide generation, ATP and avian uncoupling protein expression. It was suggested that a recovery period of up to 3 hours may help alleviate cellular damage and maintain meat quality by reducing the rate of energy metabolism and scavenging of free radicals formed.

Lund et al. (2013) have reported that pathological lesions and causes of death of DOA broilers at a Danish abattoir were investigated in a cross-sectional study. Analyses of pathological diagnoses revealed that DOA broilers can be divided into two main categories, lung congestion and trauma, based on the chronicity of the lesions, both of which are primarily related to management and handling procedures. Most DOA broilers examined (74.2%) were estimated to have died as a consequence of events during pre-slaughter handling underlining the importance of increased focus on handling-related factors to reduce DOA rate.

Medina-Vara et al. (2016) examined physiological responses to transport in broilers in Mexico. It was reported that only partial pressure of oxygen in the blood (pO2) and blood oxygen saturation and plasma concentrations of sodium and potassium were alter by transportation. The study did not related to any physiological changes to journey or environmental factors or challenges and so offers little insight in to the animal outcomes resulting from transportation.

Potential novel biomarkers for the detection and quantification of transport stress in turkeys have been investigated by Lecchi et al. (2016). Turkeys were subjected to 2 hours of road transportation. The expression levels of five circulating micro-RNAs (miRNA) were detected and assessed by quantitative polymerase chain reaction using

TaqMan® probes, as potential biomarkers of stress. The areas under the receiver operating characteristic curves were then used to evaluate the diagnostic performance of micro-RNA (miRNA). This study suggests that the expression levels of circulating miR-22, miR-155 and miR-365 are increased during transport-related stress and that they may have diagnostic value to discriminate between stressed- and unstressed animals.

Matur et al. (2016) have investigated the role of environmental enrichment of hens on subsequent response to transport stress. It was reported that although environmental enrichment did not alter the effect of transport on lymphoid organs, it activated the non-specific immune system, cellular and the humoral branches of the specific immune system by increasing heterophil functions, CD8+ cells and antibody production, respectively. Therefore, environmental enrichment suggested for improving animal welfare of the hens may also be beneficial to improve the immune system of birds exposed to stress e.g. transportation.

Zhao-Yang et al. (2017) have examined the consequences of potential transport stress in chicks. Birds were subjected to 2, 4 or 8 hours of transport and the impact upon cardiac ion transport and homeostasis was determined. The results showed that transport stress increased the weight loss and the CK activity in chicks and these changes were associated with disturbed the ionic (K^+, Ca^{2+}, Mg^{2+}) homeostasis and inhibited the ATPase (Na^+-K^+-ATPase, Ca^{2+}-ATPase, Mg^{2+}-ATPase and Ca^{2+}-Mg^{2+}-ATPase) activities. Transport stress increased the ATP content and downregulated the gene expression levels of the ATPase associated subunits in the chick hearts. It was concluded that transport stress disturbed the ionic homeostasis via modulating ion transporting ATP-ases and the transcriptions of the associated subunits, and ultimately induced weight loss and heart injury in chicks.

Wein et al. (2017) have reported that transport related stress is associated with an activation of a pro-inflammatory response in peripheral blood leucocytes in young turkeys. It was proposed that the physical and physiological challenges experienced during transport may explain the susceptibility of turkey pullets to opportunist pathogens in the immediate post-transit period.

Hollemans et al. (2018) have investigated the effects of early feeding upon life long performance and behaviour in newly hatched chicks and possible interactions with the imposition of transport stress upon the chicks. No effects of transport or its interaction with moment of first nutrition were found on performance. At 3 days post hatch, transported, early-fed chicks had a greater latency to stand up in a tonic immobility test than transported, delayed fed chicks, but only in chicks that were transported. At 30 days post hatch, however, latency was greater in transported, delayed-fed chickens than in transported, early-fed chicks. This may indicate long-term deleterious effects of delayed nutrition on fear response in transported chickens. The combination of transport and early nutrition may influence the chicken's strategies to cope with stressful events in early and later life.

The assertion that modern broiler chicks have higher metabolic rates compared to their immediate genetic predecessors appears to have resulted from a single EFSA Opinion (2004) but without any supporting published evidence. The statement offered in that Opinion may have derived from one or two previous publications describing weight loss in post-hatch chicks BUT not differences or effects attributable to metabolic rate or differential genetic selection for performance. There are numerous reports relating to the utilisation of yolk reserves, residual yolk and other substrates in embryos and newly hatched chicks. The effects of genetic selection upon these measures are poorly characterised. As in the case of metabolic rate methodological differences make many comparisons invalid and no comparisons within broiler lines are available that indicates any increase in demand or reserve mobilisation or depletion in higher performing modern lines. However, there are many publications that appear to be reliable that indicate yolk and body reserves of energy, substrates and water are adequate to support chicks during the first 72 hours of life. The published data, at this time, do not support the proposal that an increased metabolic rate in modern, rapidly growing lines of broilers will result in a more rapid depletion of reserves of energy, substrates and water that will compromise the welfare of the birds in the currently prescribed period for transportation. There is evidence that additional imposed stressors during this period will accelerate mobilisation and utilisation of reserves and thus control of the chick's thermal environment and optimal handling and support during the post-hatch period are paramount. There is considerable evidence that delayed feeding or inanition in broiler chicks may have effects upon subsequent effects upon growth and development. There does not appear to be complementary evidence indicating that these changes are associated with an increased stress or risk to the chick's welfare or health during the immediate post-hatch of maximum transport period. There is little evidence relating the physiological and metabolic status of the post-hatch chick to bird welfare. It is not know at what point depletion or exhaustion of energy or water reserves constitutes an unacceptable stress upon the chick and is associated with a decrease in welfare and thus constitutes a concern. There is a paucity of published information relating the metabolic status of newly hatched chicks during inanition over the first 3-4 days of life to their physiological condition and their welfare. Only a few studies have examined the reserves of specific substrates and metabolites, their availability and mobilisation and how these relate to the well being of the chick. In this context the measurement of circulating levels of metabolites and appropriate hormones and other biomarkers would usefully inform assessment of metabolic, physiological and stress status of newly hatched chicks. This approach would best define the upper physiological limit for a period of inanition post-hatch.

There are many published studies describing biomarkers and other measures that can be applied in poultry transport studies. These include all the traditional stress biomarkers as well as the expression levels of circulating micro-RNAs (miRNA), activity of the immune system e.g. CD8+ cells and antibody production. Other studies have described changes in ionic homeostasis in chickens e.g. (K+, Ca2+, Mg2+) homeostasis and inhibited the ATPase (Na+-K+-ATPase, Ca2+-ATPase, Mg2+-ATPase and Ca2+-Mg2+-ATPase) activities in response to transportation. Relating changes in these parameters to bird welfare is particularly a challenge for newly-hatched chicks and further studies of the welfare of these birds, and the acceptable period post hatch druing which birds do not need feeding should be determined.

HORSES

The recently published Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). ‘Good practices for animal transport in the EU: Horses ’ (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/) have identified the main areas of welfare concern for the transport of horses and have addressed these through identification and integration of recommendations for good and best practice from scientific knowledge, scientific literature, experiences and information from stakeholders.

The majority of potential hazards identified for transported animals are common to all the species e.g. cattle, pigs, poultry, sheep and horses (Van Reenen et al., 2008). EFSA identified the following main hazards for horses transported for slaughter (EFSA, 2011):

1. Poor inspection of horses prior to transport resulting in the transport of animals that are diseased, injured or otherwise unfit to travel;
2. Lack of appropriate individual penning, resulting in aggression between horses, injury and exhaustion;
3. Lack of appropriate penning, resulting in reduced ventilation leading to heat stress, exhaustion and disease;
4. Lack of appropriate penning, leading to inability to balance or maintain posture resulting in injury, exhaustion and disease;
5. Lack of appropriate penning, causing direct physical injury and exhaustion;
6. Poor watering provision at all stages in the transport process resulting in dehydration, heat stress and exhaustion;
7. Journey length with long duration resulting in disease, injury and exhaustion.
8. Poor driving and/or road/sea conditions causing continual postural adjustments resulting in disease, injury and exhaustion.

Practical observations (World Horse Welfare, 2011) have shown that horses sourced for slaughter often are not accustomed to transport (similar to other species but in contrast to many sports horses), making transport more stressful. Therefore the distinction between broken and unbroken horses is important. Unbroken horses that cannot be led by a rope will probably experience more stress than broken horses that have experience with transportation. It was also observed that the horses often are not completely physically fit. The latter stresses the need for critical assessment of fitness for travel at the place of departure. Horses intended for slaughter were frequently recognised to demonstrate signs of poor welfare and health, such as pre-existing disease, injury, exhaustion (based on behavioural indicators such as head resting, high motivation to rest in recumbency), dehydration (based on behavioural indicators such as those outlined in World Horse Welfare et al. (2014), pain or discomfort (based on behavioural indicators such as facial tension, stance, etc.) and stress (based on behavioural indicators). Underlying causes for the problems identified and thus also preventive measures are interlinked. Dehydration can be prevented by adequate water provision (World Horse Welfare, et al., 2014) and prevention of heat stress. The need to balance on a moving vehicle, requiring horses to expend a substantial amount of energy and can result in fatigue or even exhaustion. There are several recommendations to prevent this happening. Injuries can also be prevented by minimising stress through the right vehicle design and good handling.

The transportation of horses will now be considered under the headings identified above and derived from the structure of EC 1/2005 and associated annexes.

Journey times – Rest Stops

Friend (2000) has investigated dehydration, stress, and water consumption in horses during long-distance commercial transport. Adult mares and geldings were deprived of access to feed and water for 6 hours and assigned to one of the following treatments: (1) penned/watered, (2) penned, no water (3) transported, offered water (4) transported, no water. Horses were transported on a commercial, single-deck, open-top, 15.8 m long trailer divided into four compartments to accommodate the two transported/watered and two transported groups at 1.77 m^2 per horse. At 8, 17, 22, 27, 30, and 33 hours after initiation of transport, the truck returned and stopped for 1 hour to allow for data collection and to give the transported/watered and penned/watered horses 10 minutes of access to water in individual buckets. Treatments for the non-watered horses were terminated after 30 hours due to dehydration and fatigue, whereas the watered horses (penned/watered and transported/watered) could continue for another 2 hours. Mean weight loss after 30 hours was greater in the penned (57.1 kg, 12.8%) and transported (52.2 kg, 10.3%) groups than in the transported/watered (20.7 kg, 4.0%) and penned/watered (17 kg, 3.5%) groups. Respiration, heart rate, sodium, chloride, total protein, and osmolality were significantly elevated in the non-watered horses and sodium, chloride, total protein, and osmolality greatly exceeded normal reference ranges, indicating severe dehydration. Although not statistically significant, the horses penned in full sun, with or without water, had a dehydration response that was slightly greater than that of the transported horses. Plasma cortisol concentrations had a significant time × treatment interaction ($p < 0.0001$), in which the penned/watered and transported/watered horses remained relatively consistent, whereas the transported and especially the penned horses' plasma cortisol concentrations greatly increased. It was concluded that transporting healthy horses for more than 24 hours during hot weather and without water will cause severe dehydration. In addition it was suggested that transport for more than 28 hours even with periodic access to water will likely be harmful due to increasing fatigue.

> Transported horses are at risk of dehydration. Transporting healthy horses for more than 24 hours without water in hot weather will cause severe dehydration. Transport for more than 28 hours even with periodic access to water will likely be harmful due to increasing fatigue.

Long Journeys

Marlin et al. (2011) examined the welfare and health of horses transported for slaughter within the European Union. The study demonstrated that acute and chronic injuries and lameness, ranging from mild to severe, were prevalent in animals before departure from their origin in Romania and a significantly higher prevalence of severe injuries and lameness was found later in animals on arrival at the slaughterhouses in

Italy. It was reported that there was frequent lack of compliance with Council Regulation (EC) No. 1/2005 on the Protection of Animals during Transport. In addition, it is suggested that many of the practices or malpractices observed in the study had evolved for economic reasons i.e. to ensure that the long distance transport of horses for slaughter in Italy for human consumption continues to be economic. It was proposed that the practices appear to cause marked suffering to the animals involved. It was suggested that horses do not appear to tolerate long distance commercial transport as well as other farm animals. This suggestion was based upon the study finding of a high prevalence of clinical signs of disease and injuries following the long distance transportation of horses.

The welfare of horses transported to slaughter in Canada has been investigated by Roy et al. (2015). The study involved the assessment of welfare and journey risk factors affecting welfare. The study involved 3940 horses from 150 loads transported to a slaughter plant in Canada. Multivariable regression analyses were used to examine the association between journey characteristics and welfare outcomes. Five percent of the horses arrived from within Canada (median journey duration 12 hours), and 95% arrived from five states in the USA (median journey durations 15- 36 hours). Seven percent of horses from Canada and 1% of horses from the USA arrived with pre-existing conditions. Five percent of the horses had a body condition score B3 (scale 1-5) and less than 1% were lame. Six horses from the USA (0.16%) arrived in a non ambulatory condition. A linear mixed model showed that plasma total protein concentration increased with journey duration. No pre-transport measurements were possible and lairage and slaughter may have affected some of the results. Fewer severe welfare problems were identified than in similar studies conducted previously in the USA. However, multivariable analyses suggested that long journeys were associated with an increased risk of dehydration.

Padalino et al. (2015) have reviewed the health problems and risk factors associated with long haul transport of horses in Australia. Records were analysed pertaining to road transport of horses from Perth to Sydney (duration 3.5 days and over 4000 km in length) over a two year period in order to quantify the incidence of transport related issues and identify risk factors. Transportation resulted in health problems in 2.8% of the transported horses, and in fatalities in 0.24%. Based on the veterinary reports of the affected horses; the most common issues were respiratory problems (27%); gastrointestinal problems (27%); pyrexia (19%); traumatic injuries (15%); and death (12%). Journey duration and season had a significant effect on the distribution of transport related issues ($p < 0.05$); with a marked increase of the proportion of the most severe problems (i.e., gastrointestinal; respiratory problems and death) in spring and after 20 hours in transit. Journey duration and season were risk factors for the development of transport related health problems, while breed, sex and age did not predict disease or injury risk.

Padalino et al. (2017) have examined Immunological, clinical, haematological and oxidative responses to long distance transportation in horses. The study involved measurement of immunological, clinical, haematological, inflammatory and oxidative parameters in an experimental group (EG) of ten horses, comparing them with six horses of similar age and breed used as a non-transported control group (CG). Long distance transportation induced an acute phase response impairing the cell-mediated immune response. Clinical examinations, including assessing capillary refilling time and body weight loss, and the monitoring of redox balance may be useful in evaluating the impact of extensive transport events on horses. It was suggested that more studies are required to elucidate the link between transportation stress, the immune system and the acute phase response in horses.

In EU (transport from Romania to Italy) horses were often transported with pre-existing conditions. Elsewhere this ranged from 3-7% (Australia and Canada). Journeys of over 20 hours were associated with a marked increase in disease and injury.

Thermal conditions and Ventilation

Purswell et al. (2006) determined air exchange rate in a horse trailer during road transport. Air exchange rate was measured at ten locations within a four-horse trailer (internal volume 18.5 m^3) using tracer gas decay measurement to assess the adequacy of ventilation. Three vehicle speeds (13, 48, and 97 km h^{-1}) and three window configurations (all windows and roof vents closed, all windows open, all windows open and roof vents open forward) were tested with and without animals present in the trailer. External air temperature ranged from 22.3°C to 28.3°C with an average of 25.3°C, and internal air temperature ranged from 29.9°C to 34.8°C with an average of 31.3°C with animals present. Air exchange rate increased with vehicle speed and open window and vent area. The average air exchange rate over all vehicle speeds and ventilation configurations was 0.52 min^{-1} with animals present and 0.76 min^{-1} without animals. Without animals present, the maximum mean exchange rate was 1.42 min^{-1} at 97 km h^{-1} at the rear left window with all windows and vents open; the lowest mean exchange rate was 0.12 min^{-1} at 13 km h^{-1} with all windows and vents closed at the lower position of the rearmost stall divider. With animals present, the maximum air exchange rate observed was 0.84 min^{-1} with all windows and vents open and traveling at 97 km h^{-1}. Ventilation in the trailer was not adequate when compared to recommendations for stabled horses for any combination of vehicle speed or ventilation configuration. It was concluded that increasing open vent area, either by increasing the number and size of roof vents or the size of windows in the sidewall, would be the most cost-effective means of increasing air exchange in a horse trailer.

Ventilation in horse transporters is inadequate in comparison to recommendations for stabled horses.

Transport Practices

Clark et al. (1993) studied the effects of orientation during transportation on heart rate and cortisol secretion on horses during very short transportation. It was proposed that general transportation stress may have masked some of the effects of orientation however it was concluded that having horses facing away from the direction of travel was advantageous as the horses were better able to maintain balance.

Waran and Cuddeford (1995) investigated the effects of loading and transport on the heart rate and behaviour of horses. The behaviour and heart rates of horses were measured during loading and confinement in a stationary vehicle and transport for 25 minutes. Evasive behaviour during loading was only observed in very young horses, and the time the yearlings took to load (368 seconds) was much greater than that of 2-year-olds (29.5 seconds) or 3-year-olds (2l.5 seconds) and those over 3 years of age (5 seconds); however, although mean heart rates during loading were elevated in all groups they did not differ significantly between age groups. In the second study, the behaviour and heart rates of seven horses were compared in either a stationary or a moving vehicle. Horses were tested with a companion horse to remove any influence of isolation, and hay was available. During transit the horses adopted certain body postures (e.g. forelegs forward and apart and hind legs apart) that were thought to be due to their need to brace themselves in order to maintain balance. They also spent less time feeding (27% of scans in transit vs. 72% in the stationary vehicle). Heart rates were on average 18 beats per minute higher in the transported compared with the stationary situation. It was suggested that although loading is particularly disturbing for naïve horses, it is also stimulating in some way for more experienced horses. It was concluded that the elevated heart rates and abnormal body postures that were recorded during 25 minutes of transport indicated that transport is at least physically stressful for horses and may cause weight loss and fatigue in horses on longer journeys.

Waran et al. (1996) have examined also the effects of transporting horses facing either forwards or backwards. The study involved transporting six thoroughbred horses in pairs in a lorry on one journey facing in the direction of travel, and on another journey facing away from the direction of travel, over a standard one hour route. Heart rate monitors were used to record their heart rate before, during and after the journey and the horses' behaviour was recorded by scan sampling each horse every other minute. The average heart rate was significantly lower when the horses were transported facing backwards, and they also tended to rest on their rumps more. In the forward-facing position, the horses moved more frequently and tended to hold their necks in a higher than normal position and to vocalise more frequently. During loading the average peak heart rate was 38 beats per minute (bpm) lower when the horses were backed into the horse box for rear-facing transport than when they were loaded facing forwards. However, there was no difference between transport facing forwards or backwards in terms of the peak unloading heart rate, or the average heart rate during loading or unloading. The horses seemed to find being transported less physically stressful when they were facing backwards than when they were facing forwards. These findings are consistent with those of Clark et al. (1993).

Smith et al. (1994) investigated the effects of body position and direction preferences in horses during road transport. To determine if horses have preferences for facing forward vs. backward in a horse trailer, the authors analysed the percentages of time horses spent in different body positions and directions while standing in a moving or parked horse trailer. Body positions and directions of 8 thoroughbred geldings were videotaped while horses were transported singly and untethered in a 4 -horse stock trailer over a 32 km route of country roads or while the same horses were untethered in the same trailer stationary. Analysis of the logit-transformed percentages of time horses spent in different directions indicated that they spent significantly more time facing backward when the trailer was in motion, but not when it was parked. Several horses displayed strong individual preferences for the directions they faced during road transport. The study confirms the proposal that horses should be transported facing away from the direction of travel.

The effects of lighting conditions on the welfare of horses being loaded for transportation have been examined by Cross et al. (2008). In this study 8 horses were initially trained to enter a trailer for a food reward, and were then loaded into an enclosed trailer either from a dark or lit arena and into a dark or lit trailer. Heart rate increased from the start to the end of each test in all treatments, suggesting that the horses experienced some fear of the loading process. However, there was no effect of lighting treatment on the increase in heart rate or the maximum or mean heart rates. Neither was there any effect of treatment on the speed of loading or number of refusals, which, when examined with the heart rate data, suggests that there was no effect of lighting treatment on the horses' fear of loading. However, horses loading from a lit arena were more likely to turn away from the trailer or lower their head than horses loading from a dark arena. In addition, those loading from a lit arena to a dark trailer sniffed the ground more, showing increased exploration of their environment. It was concluded that the amount of fear shown by horses was not affected by lighting conditions inside or outside the trailer, but there was some evidence of negative emotions when they loaded from a lit arena, particularly when they were entering a dark trailer.

The utilisation of an on-board watering system by horses during commercial transport has been investigated by Iacono et al. (2006). The on-board watering system was installed on a commercial semi-trailer and its quantified use provided an estimate of how long water needed to be available, and determined if water consumption reduced weight loss. Three shipments of horses were studied of 16, 23 or 28 hours duration. Horses were divided into three separate compartments for each shipment and behaviour was recorded using 10 cameras installed in the trailer. While the truck was stopped, horses in each of two compartments received water during a 1 hour watering session. The third, non-watered compartment served as a control. Water was offered twice during the shorter shipments and three times during the longer journeys. The total number of horses drinking over the course of the shipments ranged from 85.7 to 100%. During the hotter (mean 31 ºC) shipment, all the horses that drank (88% of the horses) took their initial drink within the first 20 minutes of the first watering session. During the cooler journeys (mean 20 and 19ºC) shipments, it was not until 21–60 minutes that over 75% of horses initiated drinking. The apparent reduction in weight loss associated with provision of water did not reach statistical significance (9.8 kg / horse versus 17.1kg / horse) but it might be suggested that providing water would support positive welfare.

The effects of density and water availability on the behaviour, physiology, and weight loss of slaughter horses during transport have been studied by Iacono et al. (2007)
A 16.2 m, single deck semi-trailer was divided into three compartments to create high, medium, and low stocking density (397 kg/m^2, 348 kg/m^2, and 221 kg/m^2 per compartment) groups of unrestrained horses. Six shipments containing 23 to 30

horses per shipment were transported in summer for 18 to 20 hours. While the truck was stopped for 1 hour after 8 hours of transport and then again just before unloading, horses in each of two compartments received water for 1 hour from six water bowls (three bowls mounted on each side of a compartment). The third, non-watered compartment served as a control. Aggressive behaviour of the horses was recorded using 12 video cameras installed in the trailer. All occurrences of aggressive behaviour were counted from 15 minute segments of video during 2 hour intervals for each horse that was visible in each density group. Neither density nor water significantly affected aggressive behaviour, cortisol, plasma chemistry profile, dehydration, or weight loss. Aggression did not differ between the first and second halves of the shipments, indicating that fatigue had not advanced to the stage where aggression was suppressed. Individual horses, rather than density were the major cause of aggressive behaviour. However, two horses went down in the high density treatment, indicating that factors in high density could lead to increased morbidity or death.

Weeks et al. (2012) investigated the welfare issues related to transport and handling of both trained and unhandled horses and ponies. It was proposed that welfare may be improved by familiarising equines with transport vehicles and loading procedures before travel starts, and by providing thermally comfortable and well ventilated conditions during the journey. For long road journeys, rest breaks with drinking water should be given. Both trained and unhandled animals should have sufficient space and freedom to adjust their posture and to lower their heads, but maximum safe space allowances are unknown. Mares and foals should be transported together. Injury during transport is relatively common, particularly in groups of horses travelling to slaughter, and is usually associated with driver error, internal fittings and vehicle type or design, but also with mixing of animals of different sex and weight leading to fighting. There needs to be better training and monitoring to prevent such avoidable risks to horse welfare. There is also a need for more research into appropriate prophylaxis and post transport therapy as knowledge of accumulated stress and depressed immune function following prolonged and repeated transport is poorly understood.

Santos Godoi et al. (2014) have compared the effects of pharmaco-puncture versus Acepromazine on the stress responses of horses during road transport. This study compared the effects of injecting the usual dose of acepromazine (ACP; 0.1 mg/kg, intramuscularly [I.M.]) with those of pharmacopuncture (1/10 ACP dose at the governing vessel 1 [GV 1] acupoint) on the stress responses of healthy horses undergoing road transport for 2.5 hours. Four different treatments were applied immediately before loading with 8 animals in each treatment: injection of saline or ACP (0.1 mg/kg, I.M.) at the base of the neck; and injection of saline or 1/10 ACP (0.01 mg/kg) at the GV 1 acupoint. The road transport increased heart rate (HR), respiratory rate, body temperature, and serum cortisol of the untreated horses (injected with saline at the base of the neck). Pharmacopuncture at GV 1 reduced the average HR and transport-induced increase in HR at unloading, without changing the other variables. On the other hand, ACP (0.1 mg/kg) produced significant sedation and reduced the transport-induced increase in respiratory rate but without preventing the stress induced increase of cortisol. It is not clear if any recommendation should be made at this time concerning the use of sedation of pharmacopuncture for stress alleviation in transported horses.

Padalino (2015) has reviewed the effects of the different transport phases on equine health status, behaviour, and welfare. It was concluded that to safeguard horse welfare during transportation, it is important to minimise transport stress.

Loading and transport training with appropriate provision of positive and negative reinforcement are strongly recommended (McGreevy and McLean, 2007). Sport horses should be transported occasionally for pleasure riding thus decreasing the association between the truck and the competitions. As transport is a stressor even for experienced horses, it may be reasonable to give a rest period (a period with no travelling) to “frequent traveller horses.” To limit health problems post-transportation, it is important to examine the health status of the horses before traveling to provide them with electrolytes and antioxidants (vitamins E and C and selenium) and to optimise the environmental conditions inside the truck. During long distance journeys it is essential to plan rest stops (of at least 30-minute duration) every 4 hours for watering, feeding, urination (particularly for male horses), and cleaning the vehicle. Horses should not be loaded for more than18 hours without being unloaded and being able to do some physical exercise. On arrival at the destination, it is important to offer fresh water and high quality food because it is apparent that drinking and feeding are the horses' highest priority needs after transportation. Although significant research has been conducted and reported thus allowing the development of best practice management guidelines, further research is required to fully understand the relationships between transport stress, immune system status, and risk of post-transport disease development.

Padalino et al. (2017) investigated the incidence of transport related problem behaviours (TRPB) and training methods in Australia and to identify risks for and consequences of TRPB. An online survey was conducted. TRPB were classified into preloading, loading, travelling (TPB), and unloading. Training methods were classified into operant conditioning (OC), self-loading (SL), habituation (H), and no training (NT). TRPB were reported by 38.0% of respondents, mainly at loading and travelling. Training method was identified as a risk factor for all types of TRPB. Appropriate training is necessary to minimise the risk of TRPB.

Injury during transport is relatively common in horses, and the incidence of disease and injury increases markedly after 20 hours of transport. During transport horses adopt a braced position which can lead rapidly to fatigue. Rest periods when water is offered should be every 4 hours for at least 30 minutes. Horses prefer to travel facing away from the direction of travel and this appears to be less stressful for them. Poor welfare in transported horses has been associated with avoidable issues such as poor driver responses, vehicle design and mixing unfamiliar animals.

Sea and Air Transport

Thornton (2000) has reported the effect of the microclimate on horses during international air transportation in an enclosed container. The study examined 12 hour and 24 hour flights each carrying 3 horses in an enclosed container designed to prevent exposure to insect vectors. Heart rates were monitored throughout and blood samples were collected periodically. Air in the container was sampled for bacteria and fungal spores and the temperature and relative humidity were recorded inside and outside the container periodically during the flight. On the two 12 hour flights similar observations were made on three horses transported in regular open containers, which were used as controls. It was reported that heart rates during the flights reflected any agitation of the horses. Agitation was only mild and generally associated with take-off and landing. There were no changes in haematological or blood biochemical values that suggested any detrimental effects of the flights. The temperature in the container (Airstable®) was relatively constant during each flight (means ranged from 18.7 to 23.4°C) and was significantly warmer than in the cargo hold (range 13.9 to 18.3°C). Relative humidity fluctuated more widely and reflected the ambient humidity during airport stops. The numbers of bacteria and fungal spores in the Airstable® air varied during the flights but were of no apparent significance to the horses' health. It was concluded that the Airstable® proved a convenient means to transport horses on international flights and caused no discernible ill effects on the horses studied.

Stewart et al. (2003) studied the effects of air transport on the behaviour and heart rate of horses. Body temperatures prior to and after transport were measured also. Heart rate was recorded before road transport to the airport to obtain resting levels, and recordings continued throughout subsequent road and air journeys. A range of social activities, together with body postures associated with balancing and resting, were recorded over a series of 30 minute observation periods during the air journey. The air temperature and relative humidity (RH) in the aircraft were also recorded. During short haul flights (3–4 hours), 16 horses were sampled. Heart rates were significantly higher during transitional events (i.e. while loading and unloading the truck and aircraft, and during ascent and descent) than when horses were resting or when the aircraft was in flight. In level flight, horses' heart rates were close to resting levels and they would regularly rest. In comparison, during ascent and descent, social behaviour, including aggression and submission, increased, and horses were seen to regularly change body postures to maintain balance. During long haul flights (10–15 hours), 19 horses were sampled. The difference in journey length did not change how horses responded to transport events. Air temperature and humidity were highest when the plane was stationary (e.g. during loading, unloading, refuelling and delays). Although some sharp increases in heart rate and activities suggested agitation during transitional stages of air transport, these events did not appear to be frequent or long enough to be a significant welfare concern. It was proposed that horses appear to adapt well to air travel under the conditions studied.

Munsters et al. (2013) analysed heart rate, heart rate variability and behaviour (behaviour score – BS) of horses during an 8 hour air transport between the Netherlands and New York. Heart rate (HR) and heart rate variability (HRV) parameters were calculated every five minutes during the air transport. Compared with transit (40), mean HRs were higher during loading into the jet stall (67), loading into the aircraft (47), taxiing (50), and during periods of in-flight turbulence (46). During the flight, individual horses showed differences in mean HR and peak HR. By contrast with HR data, HRV data did not differ between stages or horses. BS was highest during turbulence (3.2±0.4). However, behaviour did not always correspond with HR measurements: the least responsive horse had the highest HR. Loading into the jet stall caused the highest increase in HR and was considered the most stressful event. During transit, HR was generally comparable with resting rates. HRV data were not found to be useful, and caution is needed when interpreting HRV data. Not every horse exhibited stress through visible (evasive) behaviour, and HR measurements may provide an additional tool to assess stress in horses.

When transported in well designed, purpose-built stalls horses appear to tolerate air transport very well and only show behavioural and physiological indications of anxiety at loading, take off and landing and with turbulence.

Welfare Measures and Outcomes

Fazio et al. (2009) have determined the physiological variables of horses after road transport. Horses transported for 3-4 hours were studied and a number of physiological variables were measured including total and free iodothyronines, body weight, rectal temperature and heart rate changes. A total of 126 horses were sampled (blood) before and after transportation. Compared to the before-transport values, increases in circulating T3, T4 and fT4 levels were observed after transport, irrespective of breed. Thoroughbreds showed higher free thyroid hormone concentrations (fT3 and fT4) levels after transport than crossbred stallions. Compared to the before-transport values, significant increases in rectal temperature and HR were observed after transport. Significant correlations between T3 and rectal temperature and body weight and heart rate were found. It was suggested that the results indicated that short road transport induces a preferential release of T3, T4 and fT4 hormones from the thyroid gland in relation to different breeds, and an increase in rectal temperature and heart rate. The data obtained suggest that the stallion's thyroid hormones and functional variables may play an important role in assessing the effects of transport stress and a horse's coping strategy.

Schmidt et al. (2010a) have examined cortisol release and heart rate variability in horses during road transport. They employed non-invasive methods of assessment of adrenocortical activity. Measures included salivary cortisol, faecal cortisol metabolites as well as heart rate and heart rate variability (HRV) in horses transported by road on short journeys (1 and 3.5 hours duration) and medium duration journeys (8 hours). With the onset of transport, salivary cortisol increased immediately but highest concentrations were measured towards the end of transport (4.1, 4.5 and 6.5ng/ml in horses transported for 1, 3.5 and 8 hours, respectively). Faecal cortisol metabolite concentrations did not change during transport, but 1 day after transport for 3.5 and 8 hours had increased significantly reflecting intestinal passage time. Compared to salivary cortisol, changes in faecal cortisol metabolites were less pronounced. Heart rate increased and beat-to-beat (RR) interval decreased with the onset of transport. Standard deviation of heart rate increased while root mean square of successive RR differences (RMSSD) decreased in horses transported for 3.5 (from 74 to 45 ms) and 8 h (from 89.7 to 59 ms), indicating a reduction in vagal tone. It was concluded that transport of horses over short and medium distances leads to increased cortisol release and changes in heart rate and HRV indicative of stress. The degree of these changes is related to the duration of transport. Salivary cortisol was proposed as a sensitive parameter to detect transient changes in cortisol release.

The same authors have studies the effects of long distance transport on sport horses using a similar approach (Schmidt et al. 2010b) That study determined salivary cortisol immunoreactivity (IR), faecal cortisol metabolites, beat to- beat (RR) interval, and heart rate variability (HRV) in transport-experienced horses in response to a 2 day outbound road transport over 1370 km and 2 day return transport 8 days later. Salivary cortisol IR was low until 60 minutes before transport but had increased 30 minutes before loading. Transport caused a further marked increase, but the response tended to decrease with each day of transport. Concentrations of faecal cortisol metabolites increased on the second day of both outbound and return transports and reached a maximum the following day. During the first 90 minutes on Day 1 of outbound transport, mean RR interval decreased. Standard deviations of RR interval (SDRR) decreased transiently. The root mean square of successive RR differences (RMSSD) decreased at the beginning of the outbound and return transports, reflecting reduced parasympathetic tone. On the first day of both outbound and return transports, a transient rise in geometric HRV variable standard deviation 2 (SD2) occurred, indicating increased sympathetic activity. It was concluded that transport of experienced horses leads to increased cortisol release and changes in heart rate and HRV, which is indicative of stress. The degree of these changes tended to be most pronounced on the first day of both outbound and return transport.

Similar approaches were employed again by Schmidt et al. (2010c) to study the effects of repeated transportation on transport naïve horses. Again the study employed measurement of salivary cortisol concentrations, faecal cortisol metabolites, cardiac beat-to-beat (RR) interval, and heart rate variability (HRV) now applied to transport-naive horses that were transported 4 times over a standardized course of 200 km. Immuno-reactive salivary cortisol concentrations always increased in response to transport but cortisol release decreased stepwise with each transport. Concentrations of faecal cortisol metabolites increased from 55.1ng/g before the first transport to161 ng/g the morning after. Subsequent transport did not cause further increases in faecal cortisol metabolites. In response to the first transport, mean RR interval decreased with loading of the horses and further with the onset of transport (1551, 1304, and

1101 msec 1 day before, immediately preceding, and after 60–90 minutes of transport, respectively. Decreases in RR interval during subsequent transports became less pronounced. Transport was associated with a short rise in the HRV variable standard deviation 2 (except in transport 1), indicating sympathetic activation. No consistent changes were found for other HRV variables. It was concluded that the transport-induced stress response in horses decreased with repeated transport, indicating that animals habituated to the situation, but an increased cortisol secretion remained detectable.

Onmaz et al. (2011) investigated the possible induction of oxidative stress in horses during transportation. The study employed 10 healthy mixed breed adult horses, transported by road on 538 km. Physical (rectal temperature, respiratory and heart rates), haematological, biochemical and oxidative stress (Malondialdehyde (MDA) and superoxide dismutase (SOD)) parameters were determined before and after transportation. Transportation induced significant increases in respiratory and heart rates, in haematocrit and in glycaemia, the other clinical, haematological and biochemical parameters remaining unchanged. The occurrence of an oxidative stress induced by a 12 hour transport period was evidenced by a marked and significant increase of the plasma MDA concentrations coupled to a significant reduction in the plasma SOD activity compared to baseline values. It was concluded that long-distance transport negatively affected the oxidant/antioxidant status in horses.

Marlin et al. (2011) examined the welfare and health of horses transported for slaughter within the European Union. The study demonstrated that acute and chronic injuries and lameness, ranging from mild to severe, were prevalent in animals before departure from their origin in Romania and a significantly higher prevalence of severe injuries and lameness was found later in animals on arrival at the slaughterhouses in Italy. It was reported that there was frequent lack of compliance with Council Regulation (EC) No. 1/2005 on the Protection of Animals during Transport. In addition, it is suggested that many of the practices or malpractices observed in the study had evolved for economic reasons i.e. to ensure that the long distance transport of horses for slaughter in Italy for human consumption continues to be economic. It was proposed that the practices appear to cause marked suffering to the animals involved. It was suggested that horses do not appear to tolerate long distance commercial transport as well as other farm animals. This suggestion was based upon the study finding of a high prevalence of clinical signs of disease and injuries following the long distance transportation of horses.

Ohmura et al. (2012) studied the changes in heart rate and heart rate variability during transportation of horses by road and air. Six healthy horses were equipped with ECG recording systems and subjected to transportation by either road or air. In horses, HR and HRV indices during road transport and air transport differed, suggesting that exposure to different stressors results in different autonomic nervous influences. The patterns of these relationships among horses appeared to be consistent within a given type of stress (e.g. road-transport conditions) but were different during other conditions (e.g. transportation by air). These differences may have been caused by distinct autonomic responses to particular stimuli.

Niedźwiedź et al. (2013) have studied the effects of 8 hours transportation on plasma total antioxidant status (PTAS) in horses. The study utilised 60 horses of different breeds aged from 4 to 10 years. Venous blood was collected and a clinical examination was performed immediately before loading horses onto trailers for8 hours transport (I), immediately after unloading them from the trailer (II), and after a subsequent 24 hour stall rest (III). The ferric-reducing ability of plasma (FRAP) was used to determine PTAS. The transportation significantly increased respiratory and heart rates. The average PTAS increased during the three samplings and it was concluded that long-distance transport increased the PTAS horses, as well as respiratory and heart rates.

Fazio et al. (2013) studied the endocrinological responses to short transportation of Equidae. The effects of short transportation on ß-endorphin, adrenocorticotropic hormone (ACTH) and cortisol changes were determined in 12 healthy stallions of Equidae (*Equus asinus* and *Equus caballus*) before and after transportation on journeys of 50 km. Blood samples were collected 1 week before transportation in basal conditions, immediately before loading and after transportation and unloading, on their arrival at the breeding station. Compared to basal and before values, donkeys showed an increase in circulating ACTH and cortisol levels after transportation and higher ACTH levels than horses after transportation. A positive and significant correlation between ACTH and cortisol levels after transportation was found. No significant differences were observed for ß-endorphin levels. Compared to basal and before transport values, horses showed higher cortisol levels after transportation and no significant differences were observed for ACTH and ß-endorphin levels in donkeys. Horses facing forward (direction of travel) showed higher ($p < 0.01$) ß-endorphin levels after transportation than donkeys; horses facing backward (the opposite direction of travel) showed lower ACTH levels after transportation. The results indicate that short transportation induces a preferential activation of the hypothalamus-pituitary-axis (HPA), with significant release of ACTH and cortisol in donkeys and only of cortisol in horses, suggesting that transportation for donkeys may be more stressful than horses.

Allano et al. (2016) have characterised the influence of short distance transportation on tracheal bacterial content and lower airway cytology in horses. Eight healthy adult horses were studied. Mucus scores, tracheal wash (cytology, bacterial culture) and broncho-alveolar lavage fluid (BALF; cytology) were obtained while stabled and following 2.5 hours transportation (with and without hay). Neutrophil counts, percentages and BALF neutrophilia frequency increased following transport without hay. No effect was observed on tracheal cytology and bacterial count. It was concluded that BALF neutrophilia could develop solely as a result of transportation or due to interactions between repeated transports, ambient temperature, head position or other environmental factors.

Messori et al. (2016) have developed a scientific and practical tool to be used to assess horse welfare after commercial transport over long journeys. A set of physical, behavioural and environmental measures was selected, covering welfare aspects of both transport and unloading procedures. The protocol was field-tested on 51 intra-EU commercial journeys arriving at different sites in Italy. Univariate analysis was implemented to look for associations between the input variables (environmental hazards potentially affecting the animal well-being during long transports) and the outcome variables (direct evaluation of the animal condition). No severe welfare impairments were recorded (i.e. dead on arrival, severe injuries, non-ambulatory animals), while milder ones were more frequent at unloading (e.g. slipping; 36.7%, reluctance to move; 9.6%). Correlations emerged between ramp angle and falling; type of ramp floor and slipping; fast gait and the presence of gaps between the ramp and the floor. The horses' behaviour was also related to the type of handling procedure used. The measures were repeatable and practical to apply and score during real-time unloading.

Rizzo et al. (2017) have assessed the effects of acupuncture on some haemato-chemical parameters in horses after road transport and exercise. Horses competed in 2 official races. The effect of transport, exercise, and acupuncture was evaluated on cortisol concentration, white blood cell (WBC) count, and leukocytes population including lymphocytes, neutrophils, monocytes, eosinophils, and basophils. It was reported that transport and exercise are potential stressors for the athlete or competition horse that may affect its welfare and physical performance. It was suggested also that acupuncture practice may influence the animals' psychological perception of stressful challenges, probably, by modulating the neural, immune, and endocrine control systems.

Padalino et al. (2018) have proposed that behaviour during transportation predicts stress response and lower airway contamination in horses. This study characterised the effects of an eight hour journey on behavioural, clinical, haematological, environmental and respiratory parameters, and attempted to to identify possible associations between factors. Twelve horses underwent clinical examination, respiratory endoscopy with tracheal wash (TW) aspiration, and collection of venous and arterial blood before (BJ) and after the journey (AJ). TW were submitted for conventional quantitative bacteriological evaluation and genetic microbiome analyses. Behaviour was assessed in stables prior to transportation and throughout the journey. Transportation caused mild, but significant, effects on fluid and electrolyte balance and an acute phase response, characterized by neutrophilia, hyperfibrinogenaemia and hyperglobulinaemia. The proportion of neutrophils in

TW, tracheal mucus and TW bacterial concentration was increased AJ, with preferential replication of *Pasteurellaceae*. Horse behaviour *en route* predicted clinical and respiratory outcomes. Thus the frequency of stress related behaviours was greatest in the first hour of the journey, and balance-related behaviours were most common in the final hour of the journey. Horses which lowered their heads less frequently *en route* and showed more stress-related behaviours had higher physiological stress (serum cortisol and heart rate on arrival), increased tracheal mucus and inflammation scores, and higher TW bacterial concentration AJ. Six horses with abnormal lung auscultation AJ proved to have had higher tracheal inflammation scores at preloading, an overall higher concentration of bacteria in their TW, and an increased percentage of neutrophils in TW at five days AJ in comparison to the other horses. While transport-related health problems are multifactorial, clinical examination, including auscultation and endoscopic inspection of the lower respiratory tract before and after journey, and behavioural observation *en route* may identify animals at increased risk of transport associated respiratory disease.

> A number of physiological and behavioural indicators have been used to assess horse welfare in transit including the HPA axis, heart rate and heart rate variability and frequency of slips and falls at unloading. Horses that have the highest physiological indicators of stress also show behavioural signs of stress and have a higher incidence of clinical symptoms of the respiratory tract.

Other issues

Padalino et al. (2016) conducted an online survey targeting people who organised horse movements. Respondents were invited to provide demographic details and information relating to their routine transportation management practices and their experiences of issues relating to the transportation of horses. Transport-related health problems had been experienced during or after transportation by horses in the care of 67% of respondents. The most common problems reported were traumatic injuries (45.0%), diarrhoea (20.0%), muscular problems (13.0%), respiratory problems (12.3%), overheating (10.5%) and colic (10.3%) and at least one case of transport associated pneumonia and 35 horses had died, most commonly from fractures, colic or pneumonia. It was concluded that there remains a substantial risk of adverse welfare and health outcomes for horses transported in Australia and management practices reported may not be compliant with current recommendations for transportation.

Summary of systematic review outputs in relation to identified issues and welfare concerns.

A general concern that is described elsewhere in the review is the concept of the mid-journey break for livestock travelling on higher standard vehicles on long journeys according the EC 1/2005 compliant journey times for that species and age of animal. Clearly this means that for young animal this tends to be 9-1-9 hours and for mature animals 14-1-14. The mid-journey break is thus considered to be 1 hour although the legislation states a minimum of one hour. Indeed currently the duration of that break is not prescribed with no official maximum time. Theoretically the length of the break might be increased to accommodate feeding and watering the animals if unloaded or perhaps on the vehicle if appropriate resources are available. However, the break could also be manipulated to accommodate other considerations such as driver breaks, drivers' hours etc. There is an over-riding consideration that journeys should be kept as short as possible and control of this is imposed through the approval of journey plans. It might be proposed, however, that research should examine the effects of different durations of journey break with and without feeding and/or watering to determine the practices that would be most beneficial to animal welfare on long journeys

CATTLE

Evidence has been provided that a new assessment system for fitness to travel in cattle should be developed and applied. There is evidence also that livestock drivers may require additional education, training, assessment tools or feedback in order to optimize the welfare of animals to be transported.

It is proposed that cattle should be familiarised with handling and loading procedures prior to journeys particularly long journeys. It was concluded in the published studies that pre-conditioning was beneficial for calves pre-transport in that they were better able to tolerate the stressors of transport and handling. In addition, the combined effect of conditioning and short-haul transport was least stressful. Conditioning had some positive effects on the performance and well-being of transported calves and should be considered when preparing calves for sale and transport.

In support of current practices and legislation there is evidence that the 24 hours rest in the lairage, with hay and water freely available, allowed the cattle to recover substantially following long journeys

A key issue is the provision of water or feed to young or unweaned calves during transportation and at control posts on long journeys. The method of delivery of water or milk and the frequency at which they should be supplied must be considered. There is evidence that calves may require feed and water every 8-9 hours and thus under current regulations it would be essential to provide these resources during a mid-journey break on journeys adhering to a 9-1-9 schedule.

The published literature suggests that calves can be successfully and safely transported in the range of THI from 30 to 80 as effective thermoregulation allowed the calves to maintain their body temperature with small physiological changes to prevent thermal stress, particularly in the summer.

Recovery periods in calves and cattle may require further detailed examination as analysis has suggested that metabolic pathways were affected up to 7 days after transportation.

Post-journey feeding is important to post transport recovery and the literature suggests that attention should be paid to design of available feeding space at commercial rest facilities as it affects eating behaviour and general activity. Doubling feeding space may increase the mean proportion of cattle eating by 30%.

There is some evidence that handling of cattle at markets may present some welfare issues in terms of incidence and severity of bruising. This should perhaps be revisited in future survey work.

Vibration in transit may be an important factor in animals' response to transport in general in relation to fatigue and postural stability. The limited literature available has characterised the main frequencies of vibration and has indicated that vibrations in the horizontal and lateral directions were lower on animals positioned perpendicular to the direction of travel than on those facing forward. Both road conditions and standing orientation had significant effects on vibration levels. Comparison with established exposure limits for humans suggests that the conditions reported may represent a risk to animal welfare. This issue might benefit from further research activity.

Ventilation of all livestock vehicles whilst on Ro-Ro ferries is a problem that requires further investigation. The limited literature available suggests that the environment in mechanically ventilated decks or vehicles will exhibit a great deal of environmental heterogeneity. Such heterogeneity can cause a build-up of moisture and airborne contaminants on the outlet end of the container and therefore may add additional stresses to the transported animals. Naturally ventilated decks or systems may perform well in still conditions, with the unsteady nature of the indoor flow-field providing sufficient fresh air to all of the animals throughout the container. It is suggested that further characterisation and analysis of vehicle thermal micro-environments during sea transport is necessary.

There are many studies that have identified potential biomarkers of stress and altered health and welfare of cattle and calves in transit. Many of these should be considered for use in future studies on cattle and calf transport. The possible biomarkers include serum antioxidant status, indicators of protein metabolism, tissue damage, acute phase responses and steroid secretion. Specific biomarkers employed in several previous studies included albumin, globulin, urea, total protein, creatine kinase, β-hydroxybutyrate, haptoglobin, fibrinogen, cortisol, dehydroepiandrosterone (DHEA), cortisol: DHEA ratio, testosterone, progesterone and total leukocyte count. In addition proportions of CD21+ cells and B lymphocytes may be useful. Hormonal markers might include cortisol, total and free triiodothyronine and thyroxine. Functional variables to be employed to assess physiological stress should include heart rate, heart rate variability, respiratory rate and rectal temperature. There are reports of the useful application of QBA (Qualitative Behavioural Assessment) in the welfare evaluation after transportation of steers.

PIGS

Published research identified in the systematic review process has drawn attention to the fact that it is necessary to distinguish between different ages and categories of pigs. Thus some welfare risks are directly related to the category of pigs to be transported, as differences in age, sex and size may be associated with different welfare needs. Piglets just after weaning have a weight of 5 or 6 kg. They are relatively weak and sensitive to low temperatures. Older piglets weighing 25-35 kg are stronger and better able to deal with long journeys compared to piglets, although perhaps not as well finishing pigs. Cull sows and boars also require special attention: the reason they are send for slaughter is often related to health problems such as lameness, injuries or disease. More research is needed to identify the factors or combination of factors with the greatest negative impacts on welfare and meat quality relative to the species, and their size, age and condition under extreme environmental conditions. The definition of stocking densities or space allowances for pigs in transit should be revisited. The calculations should be based upon pig body weights (allometrics) and take in to account any special requirements for the type of animal or for a procedure (e.g. feeding and watering). The specified space requirements for weaner piglets should be re-examined.

The recommended space allowance of 235 kg m-2 for 100 kg is often questioned as the impact of application to pigs of other body weights ages. As proposed above adjustment of space allowance calculation can be performed using available allometric equations as stated above or values for different body surface areas provided in EC 1/2005 may be employed or the recommended allowances for sea travel (EC 1/2005) may be adapted. For these reasons it is suggested that this topic or concern may be easily resolved.

Water provision and usage in transit for pigs on long journeys requires extra attention also. Published research confirms the need for the continuous provision of water (as per EC 1/2005) and emphasises the importance of this on long journeys when temperatures are elevated and the risk of heat stress is highest.

The currently available research tends to suggest that the temperature limits for the transportation of pigs on long journeys are adequate to protect the welfare of the pigs but that more studies might address the impacts of long journey time i.e. close to 24 hours when high transport temperatures prevail between 30 and 35°C. It has been suggested that some evidence supports a reduction in maximum journey time to 6-12 under such conditions.

The importance of including integrated indices of thermal loads imposed in transit for all species has been emphasised in recently published work. The including of some measure of air water content (absolute humidity) has been demonstrated in work employing enthalpy for this purpose in pig transport. Thus, the temperature time derivative (°C s^{-1}) and enthalpy time derivative (kg water kg dry air^{-1} s^{-1}) were used to assess potential thermal stress. Post-transport observation of pig behaviour suggested that journeys with higher temperature or enthalpy time derivatives were more stressed. It was concluded that time derivatives of temperature or enthalpy could be used as non-invasive welfare indicators during transport and appear to be much more sensitive than absolute values of temperature or relative humidity.

The transportation of early-weaned piglets may require further study as published evidence suggests that transport exacerbates the stress of weaning through additional stress related to factors associated with truck movement, such as noise and vibration, and by imposing an increased risk of dehydration following long journeys (>12 hours). This latter figure may indicate a proposed journey duration limit for early weaned piglets?

There have been a number of useful reports relating to transport practices for pigs. Thus the efficacy of sprinkling systems for cooling of pigs during transportation at high environmental temperatures has been investigated and this approach may require further research for application in the UK.

Similarly there are reports concerning the effects of truck suspension systems on pig welfare and product quality. It was hypothesised that transport stress may be reduced through a vehicle suspension system that provides a much smoother ride during transport, and consequently is less aversive to pigs. When compared to air suspension system, leaf suspension was associated with a greater number of skin lesions. It was proposed that the use of leaf spring suspension system negatively affects the welfare of pigs due to the increased carcass damage and resulted in poorer pork quality traits. This topic should be examined in more details in terms of full elucidation of stress responses associated with vibrations and ride type.

There are many studies that have identified potential biomarkers of stress and altered health and welfare of pigs in transit. Studies have employed growth hormones and factors to assess transport stress e.g. IGF-I and -II and IGFBPs. Measurements of acute phase protein (APP) responses to prolonged transportation are proposed as useful biomarkers e.g. Pig-MAP, haptoglobin, serum amyloid A, C-reactive protein, and apolipoprotein A-I. Some studies recommend the measurement of heat shock proteins (Hsp). More traditional markers have also been employed including cortisol, glucose, creatine phosphokinase (CPK), lactate dehydrogenase (LDH), albumin and total protein serum concentrations. Other measures include and N:L ratio (neutrophil:lymphocyte).

More recent published research advise the development and application of animal welfare indices e.g. the Animal Welfare Index (AWI) using a weighted linear sum of prevalence on animal level (3-stage) of a range of animal welfare indicators for use on farm or post-transport. Expert opinion may be used to assign weights for welfare measurements as well as stage weights, based on which an animal welfare index within stages (AWI-Stage) as well as across stages (AWI-Overall).

SHEEP

In relation to rest periods on long journeys there is published evidence that for short resting periods e.g. 8 hours there are no clear advantages in avoiding unloading and loading of the animals in the control post after long journeys. It is not clear how this information elates to the mandatory at least 24 lairage period required in law? However the same publication suggests that the welfare of the ewes was not impaired by a stop reduction from 24 hours to 16 hours. It has been recommended also that if sheep consume large quantities of feed (e.g. in lairage at a control post) after a period without access to feed and water during transportation then the animals must be allowed sufficient time to drink before a subsequent journey is undertaken.

Further evidence relating to lairage behaviour is available that addresses the consumption of feed in novel environments such as control posts after a 16 hour journey. It was reported that there was no obvious effect of a novel post-transport environment on blood biochemistry. The observed post-transport reductions in feed and water intakes in a novel environment did not impact upon the ability of the sheep to recover from the feed and water deprivation associated with transport. Other published work indicates that post-journey behaviour of sheep is important in terms of feeding and drinking. Thus, behavioural analysis post-transport demonstrated that transported ewes chose to eat before drinking and spent less time resting than controls in the first 3 hours after unloading. It was concluded that even short-journey durations may induce behavioural, physiological and thermo-physiological responses indicative of significant stress, leading to live weight shrinkage and losses.

As for other species there is strong evidence that stocking densities or space allowances for sheep and lambs should calculated according to an allometric equation relating size to body weight. The evidence indicates that the space provided by minimum legislation and calculations with a k-value of 0.021 are unacceptable, as they do not allow the sheep to adopt their preferred spacing strategy and lead to more losses of balance, slips and falls. Space provided by a k-value of 0.026 and above for shorn sheep and 0.033 for fleeced sheep, was better suited to this independent strategy and led to fewer losses of balance, slips and falls, which is considered better for the welfare of the sheep. This should be considered and optimum allowances perhaps confirmed by appropriate research and modelling.

There are a large number of physiological measures and biomarkers that might be usefully employed in further studies on transportation of sheep in order to assess imposed stress and outcomes. Published studies have used plasma / blood concentrations of cortisol, glucose, non-esterified fatty acid (NEFA) as well as the neutrophil–lymphocyte ratio (N/L) all of which are altered in sheep by transportation and may reflect thermal stress as well as the impacts other transport stressors.

Qualitative behavioural assessment (QBA) has been employed in sheep in controlled experimental conditions (using transport as a challenge) and comparing assessments against physiological variables. This approach might be usefully added to future studies on transport of all species.

A recent systematic review of welfare indicators that might be employed to assess sheep welfare on farm, during transport and at slaughter proposes the integrations of a wide range of markers and indicators to ensure an holistic picture of animal well being. That review identified 48 animal-based indicators of sheep welfare that were categorised by the Five Freedoms. Their validity as measures of welfare and feasibility for use in abattoirs were evaluated as potential measures of prior sheep welfare on the farm of origin, at market, or during transportation to the abattoir. A total of 19 indicators were considered valid. The outputs of that study might be usefully employed in future transport research.

The transportation of sheep by sea has received considerable attention in the literature particularly in relation to long-distance carriage from Australia to the middle East and South East Asia. It is proposed that whilst some of the methodologies and analysis employed maybe exploited in future animal transport research in other countries many of the practices are not acceptable in Europe and much of the evidence from such studies will not inform future policy in the UK or Europe.

GOATS

Numerous studies have reported and characterised transportation stress in goats, often in extreme thermal conditions. Thus studies describe how blood chemistry e.g. concentrations of cortisol, adrenaline and dopamine and nor-adrenaline, glucose and non-esterified fatty acids are altered in transportation stress. Subjecting goats to even 2-hour road transportation with high ambient temperatures can generate major physiological and muscle metabolism responses. As in other species driving style and animal arrangement on the vehicle can influence the welfare of transported goats. The preferred orientation of goats in transit should be considered in future vehicle and pen design. It is suggested that there is little reliable evidence on which to base policy or guidance pertinent to the carriage of goats and that this perhaps should receive increased attention.

POULTRY

There is a considerable body of published evidence relation to the transportation of poultry that might usefully inform policy, guidance and future legislation. Some of the issues have been addressed by the recently published Guides to Good Practice (DG SANTE 2017) but many concerns remain to be resolved. The published research will facilitate the development of new policy but there are also areas that might benefit from future research and which might be considered important research requirements.

The pre-transport assessment of fitness to travel in meat poultry has long been a contentious issue in terms of who should undertake the assessment or examinations and what criteria should be employed in addition to logistic problems presented by intensive, large scale production and the numbers of birds transported.

Recent published studies have employed defined criteria of fitness including lameness, illness, hock burns, foot-pad dermatitis, lesions, physical defects, cleanliness and cachexia. Birds deemed unfit on this basis exhibited higher post-transport indicators of stress. The outcomes of this approach exhibited significant interactions with stocking density. It was recommended that the approach should constitute the basis of more structured and rigorous assessment of fitness for transport in commercial practice. This topic requires further consideration.

The non-application of the concept of standard and long journeys (EC 1/2005) to poultry has resulted in an "effective" upper journey time limit of 12 hours imposed by feeding and watering intervals. This situation has raised a number of concerns that identified in previous reviews have been addressed indirectly by published research captured in the current systematic review. Thus, in the absence of a long journey definition for poultry there are no higher standard vehicles and no defined thermal limits in transport. Published evidence suggests that based on mortalities for modern broilers journeys of over 4 hours duration impose an increased risk to welfare and survival and product quality. Several publications identified in the present systematic review confirm the relationships between dead on arrival figures in broilers (and turkeys and laying hens) and journeys duration as well as relationships with other risk factors such as season and temperature. There have been previous recommendations concerning the definition of a maximum journey time to slaughter for meat poultry and perhaps this requires further consideration.

In the case of newly hatched chicks the maximum transport time is currently considered to be 24 hours if the journey is undertaken in the first 72 hours post-hatch. The available evidence suggests that this may still be appropriate based on available knowledge of yolk sac reserves and resource utilisation. However, it may be appropriate to propose future research to specifically address this issue and to provide sound scientific evidence in support of the current position or to indicate that new guidelines or legislation should be developed.

There is substantial evidence for the definition of useful thermal limits for the transportation of broilers and newly hatched chicks and the publications have been identified by the systematic review process and the limits are described in detail elsewhere in this review. It is suggested that there is sufficient evidence for the published literature to inform policy discussions specifically relating journey time and thermal transport micro-environments and ventilation requirements for poultry. In addition, it is suggested that may be a need to revisit the prescribed feeding and watering intervals for meat poultry through future research. As mentioned previously, because birds transported in crates or the drawers of modular systems, it is not practicable to feed and water them. This highlights the importance of short transport times and careful control of overall fasting times before slaughter such that a balance is struck between the requirements of slaughter hygiene and those for animal welfare. Although there is a body of sound published research addressing the transportation of spent laying hens this must still constitute an area requiring further and specific consideration and investigation in relation to travel times, temperature limits and ventilation.

In the meat poultry industry there is a significant increase in mechanisation and automation. These changes have involved the introduction of mechanical methods of bird catching, handling, loading and unloading followed by automated slaughter methods. The design and operation of these systems very often determines the design and operation of transport containers and/or the vehicles carrying them e.g. truck ventilation regime. There are published studies relating to the performance and effects of each of the components of the systems. It is suggested that at this time there are no major areas of concern in these systems identified by reliable scientific studies but that a future review of the integrated systems may be merited.

There are numerous published studies describing biomarkers and other measures that can be profitably applied in poultry transport studies. These include all the traditional stress biomarkers as well as the expression levels of circulating micro-RNAs (miRNA), activity of the immune system e.g. CD8+ cells and antibody production. Other studies have described changes in ionic homeostasis in chickens e.g. (K^+, Ca^{2+}, Mg^{2+}) homeostasis and inhibited the ATPase (Na^+-K^+-ATPase, Ca^{2+}-ATPase, Mg^{2+}-ATPase and Ca^{2+}-Mg^{2+}-ATPase) activities in response to transportation. Transport stress increased the ATP content and downregulated the gene expression

HORSES

Evidence was identified indicating that transporting healthy horses for more than 24 hours during hot weather and without water will cause severe dehydration. In addition it was suggested that transport for more than 28 hours even with periodic access to water will likely be harmful due to increasing fatigue. This work confirms the travel times presented in EC 1/2005. Some studies have recommended that on long journeys horses have a rest stop every for 4 hours of at least 30 minutes duration during which they are provided with water. It is suggested also that horses should be prepared for long distance transport by pre-journey administration of electrolytes and antioxidants (vitamins E and C and selenium). The efficacy of this strategy requires confirmation.

There is continuing research concerning the orientations of horses in vehicles during transportation. Most of the work confirms the proposal that horses should be transported facing away from the direction of travel.

There is some evidence suggesting that ventilation of horse vehicles should be optimised. It was concluded that increasing open vent area, either by increasing the number and size of roof vents or the size of windows in the sidewall, would be the most cost-effective means of increasing air exchange in a horse trailer. The area of environmental control in horse vehicles should receive further attention as should the specification of optimum thermal environments as there is a paucity of high quality of published research in these areas. Despite acknowledgement in the literature of "frequent traveller horses" there is little research on the long term impacts of repeated exposure to transport stress.

Equine transport studies have employed a very wide range of biomarkers and other measures to assess transport stress and the impacts of transportation upon the horses. These have included rectal temperature, heart and respiratory rate and heart rate variability, plasma concentrations of ß-endorphin, adrenocorticotropic hormone (ACTH) and cortisol, salivary cortisol, faecal cortisol metabolites, haematocrit and glycaemia, thyroid hormone concentrations (T3, T4 and fT4), plasma total antioxidant status (PTAS), markers of oxidative stress (Malondialdehyde (MDA) and superoxide dismutase (SOD)).

Thus, the review process has identified key areas of concern where policy and guidance might be developed and applied based upon existing and reliable scientific evidence. In addition other issues have been identified that currently constitute gaps in scientific knowledge and might be regarded as potential research requirements that will require extensive and detailed discussions and prioritisation.

Gaps in Knowledge

Key knowledge gaps identified in the review exercise and welfare during transport assessments

Throughout this exercise a number of gaps in knowledge, or a lack of quality scientific papers, have been identified, and the main areas where research is lacking are highlighted here. General areas where there is a lack of evidence are highlighted first, followed by species specific issues where there is insufficient evidence to inform policy.

Species or animal groups where there is little research

In the first instance the screening process identified species, types of animal or components of the journey for which there were few or no papers available in the literature. Research has focused on largely on the slaughter population (except in horses where most research has focused on racing or leisure horses), and there are no papers at all on the transport of breeding bulls, boars, or rams, or on donkeys/mules or foals. Further there is only a small amount of information on other animals (less than 5 papers): dairy cows, sows, ducks and ducklings, layer hens and pullets, turkeys and turkey poults, and horses destined for slaughter. In addition, although there has been a reasonable amount of work on the transport of goats, this has been largely in tropical regions under conditions that do not compare with EU transport regulations or conditions, and are not very useful in informing policy in the UK. As has been shown from the limited amount of work there is available healthy young animals destined for slaughter are able to cope better with the slaughter journey than older animals at the end of their productive lives (e.g. cull breeding stock, end-of-lay hens), where chronic disease, injuries or low body condition may interact with responses to the stressors encountered in transit. Thus research conducted in prime production animals should not be used to translate directly to other livestock.

Components of the journey

Journeys are a complex form of stress for animals, and journey structures can be complex and formed of a number of components as the animal moves from the farm to their final destination. When the identified papers in the review were allocated to topic within species a number of other under-researched areas were also identified. In particular there were almost no papers on the **impact of markets on welfare**. This is an important omission as a number of questions have been asked about how animals should be treated in markets (for example, whether water should be provided, whether these can constitute a rest period in slaughter journeys) which cannot be adequately addressed from the available evidence. In addition, the **fitness to travel** of cattle and sheep, and the **impact of feeding and watering** and long journeys compatible with EC 1/2005 regulations in sheep and horses have not been much considered. As with markets, whether food and water should be supplied to sheep in transit at all has been raised in the consultations reviewed in this exercise and the available literature does not allow this to be addressed fully.

Resting times and the provision of food and water

One of the priority areas identified in the review processes has been the disparity in the social regulations relating to drivers hours and the journey times presented for livestock in current regulations (e.g. EC 1/2005). For all livestock species on long journeys it is clear that this disparity leads to problems of scheduling or causes some economic pressure by requiring 2 drivers for some types of long journey. The definition of rest periods as they relate to drivers rest periods requires attention. Harmonisation of the driving regulations with animal welfare in transport regulations is desirable but there is no **research to determine if the various proposed travel time combinations that would facilitate harmonisation have any positive or negative impacts on animal welfare**. This issue is a key research requirement.

For long journeys from the UK (regardless of purpose) there are a number of concerns that should be addressed. What constitutes a rest period (e.g. if time at market or on board a ferry can be considered as rest or a neutral period), whether food and water should be supplied and whether a maximum time for a rest period should be assigned are causes for considerable concern for stakeholders. **Research should examine the**

effects of different durations of journey break with and without feeding and/or watering to determine the practices that would be most beneficial to animal welfare on long journeys. The thermal environment during ferry transport is poorly understood as there a very few publications in the field. **Research is required to better understand optimum ventilation strategies for vehicles on-board ferries**. The limited publications indicate that there are key differences between passive and mechanical ventilation regimes on stationary vehicles on ferries and this topic requires further elucidation. **The better definition of how time in markets should be designated**, and what might be required to optimise welfare in relation to the entire "legal" journey is another research priority.

Temperature or thermal comfort zones

Another key area is the application of temperature limits to all animals of one species regardless of age or physiological status. This is clearly inappropriate as calves and piglets will require very different thermal micro-environments to more mature animals. Surprisingly the systematic review did not identify published research of high quality that might inform the proposal of appropriate temperature regimes for animals of different ages / maturity with differing thermoregulatory capacities. New research to address the **definitions of temperature limits for piglet and calves** should be a future research priority.

Issues relating to cattle and calves

The key unresolved issues relating to the transport of cattle and calves which require further research to address adequately are:

(1) Head space or clearance above cattle in transit is still an issue. Although there is some evidence that a space of 20 cm above the withers reduces carcase bruising, more data are required to characterise optimum practice from welfare and ventilation perspectives.

(2) Long journeys of calves constitute a major concern. A number of research questions have not been addressed currently by the literature including:

a. What is an appropriate age at weaning and what should be the lower age limit for transport?
b. Are calves able to drink (and do they drink) on vehicles equipped with unfamiliar nipple systems or other watering systems?
c. Is the currently employed 9-1-9-24 travel time structure able to adequately protect calves in transit e.g. long journeys (including export for fattening)
d. Should calves be provided with feed / water during the mid-journey break under the current legislation and if so what are the best methods to ensure calf welfare?
e. What are the long term health and welfare consequences for calves of current practice on long journeys

Issues relating to pigs

There are a number of specific issues relating to the transportation of pigs that were identified at the time of the implementation of EC 1/2005 and in subsequent review processed and which have remained unresolved since.

(1) Research is available that suggests that factors affecting the welfare of pigs in transit include the type of farm system from which the animals came (e.g. outdoor organic or straw yards or indoor on slats). The available research suggests that these factors may have more impact upon pig welfare than journey time per se. Presumably this relates to the previous experience of pigs of handling, mixing and containment, but further research would be useful to determine the influence of these effects, and whether this information can be used to improve welfare in transit.
(2) It is currently recommended that pigs should not be fed less than 6 hours before transport either from the origin or from a control post on long journeys, and there is evidence of higher mortality in pigs that have not been fasted before transport. However, there are also contradictory data that suggest animals that have only experienced food withdrawal of 1 hour are in better welfare than pigs

which have experienced longer periods of food withdrawal. It appears that the 6 hour fasting advice is based on limited published information concerning “motion sickness” in pigs. This topic should be addressed further and requires further research to confirm that this is appropriate practice. In addition, improvements in vehicle design may help to reduce the incidence of motion sickness in pigs that should be included in any new research in this area.

(3) The maximum stocking density for pigs is presented as a single figure (235 kg m^{-2}) on an area basis and primarily applies to pigs of around 100kg body weight. As with other species it is recommended that allometric equations be used (rather than standardised weight per floor space) and these have been determined for cattle and sheep (see Policy Recommendations). For pigs, however, further research is required to determine the optimum stocking densities (space allowances) for pigs over a wide range of body weights for different vehicles and thermal conditions.

(4) Head space is another issue that may require further research. The recommendation that there should be 15 cm above the highest part of a pig standing in a natural position has been the cause of much debate. Further research is necessary to establish the optimum head space for pigs of different sizes in relation to animal movement and ventilation requirements (which will differ in passive and mechanically ventilated vehicles).

(5) Mechanical ventilation regimes and throughputs should be further investigated (beyond the research currently available) to ensure that ventilation will be adequate to ensure thermal comfort in large pigs on stationary vehicles under hot weather conditions.

(6) There is evidence that unloading and loading constitutes a significant stressor for pigs, and can reduce overall welfare during transit. This can conflict with requirements to unload pigs at rest stops. Further research may be needed to determine the optimal handling and management strategy to allow pigs to rest with minimal stress.

Issues relating to sheep

A number of issues have been identified by the current and previous review processes that require further consideration:

(1) It has been demonstrated poor driving style puts sheep at risk of stress, postural instability and injury, particularly as sheep usually stand during transport. It has been proposed that vehicle motion and driving style should be automatically monitored and recorded on sheep vehicles on long journeys by the fitting of accelerometry packages to vehicles. Whilst this is a good and recommended innovation, there should be trials on the validation of this proposal in terms of the effect upon animal welfare or productivity.

(2) As with other species there is concern that inadequate floor space and head space for ventilation and thermal control on long journeys may increase the risk of heat stress. This area should receive further attention as there is little published information that might better inform new policy or advice.

(3) The provision of water on-board vehicles carrying sheep is not well studied in terms of use, efficacy and outcomes in relation to drinker design and operation and environmental conditions, space allowance and journey time. However, if rest periods are to be taken on-board, then whether access to water can be feasibly managed, and whether sheep will drink under these conditions, or suffer welfare consequences otherwise, needs to addressed. Dehydration is a risk in transported sheep as, despite the resilience of this species in the face of water withdrawal, under transport conditions in hot weather dehydration may occur relatively quickly. This area might be better informed by new future research.

(4) The provision of water for sheep in markets is a requirement. The limited available research suggests that there may not be utilised by sheep where journeys are not excessively long but the motivation to drink under a range of environmental and transport conditions has not been adequately addressed in previously published research. This topic might be better informed by new research initiatives.

Issues relating to poultry

Poultry represent a category of livestock in which there are some issues and areas on concern which were apparent at the implementation of EC 1/2005. Some of the legislative component of the Regulation had their origins in previous legislation and did not take full account of the scientific research available and reviewed in EFSA Opinions and other sources in the period 2002-2004. As a consequence subsequent reviews identified omissions and/or shortcomings in the Regulation. Many of these have yet to be addressed in term of both policy and further research. Some of the key issues are:

(1) Although it is recommended that specific thermal limits can and should be defined for broilers from the current evidence (see Policy Recommendations), there has been little work on the transport of point-of-lay hens, end-of-lay hens and turkeys (as described above). Specification of thermal comfort zones for these groups will require further research, as these animals have very different metabolic responses to broiler chickens and cannot be considered to have similar requirements. It is proposed that policy should be developed to address the issue of the thermal requirements of poultry in transit and that further research may be required to provide important fundamental evidence

(2) Another important issue is wetting of poultry prior or during transport as, in cold conditions, the disruptive effect of water on bird insulation will greatly compromise thermoregulation resulting in potentially severe cold stress, particularly for some birds in some locations on the transporter. Although much of the underpinning science in this specific area is available more research might be required to inform improved policy.

(3) The transport of newly hatched chicks also requires further examination. The available research suggests that journey time limits (based on yolk sac resource utilisation) are consistent with good chick welfare at this time. However, it has been suggested that with developments in breeding and new genetic lines these conclusions may not be safe for modern birds and that new specific research addressing this assertion is merited.

(4) An area of improvement for newly hatched chick transport has been identified by the industry and requires further investigation. Thus changes in chick box design to facilitate better ventilation and control of the thermal micro-environment might improve chick welfare and may require changes in the permissible stocking density / space allowance for chicks. This area should be studied as it offers a number of other potential benefits if proved appropriate.
(5) Inspection of poultry in respect of fitness to travel has long been a controversial issue and there are no new studies that better inform the issue. The development of an on-farm inspection guideline might facilitate progress but it is difficult to envisage the implementation strategy across the industry.
(6) Early feeding of newly hatched chicks has been recommended to improve welfare during long transport to farms. It is not clear from published research if the optimum method for delivery and composition of feed and water prior to farm placement has been established, and new research may help to clarify this issue.
(7) Provision of water to poultry in transit (on different types of journey) has been proposed and various systems have been considered. There is a lack of published information that might inform decisions on these recommendations. Further investigation is merited.
(8) The head space / clearance for poultry in transport containers is still the subject of extensive debate. The benefits and disadvantages of more head space to allow standing and/or improved ventilation are the central matter so of concern. There is no new evidence available in the literature to inform this issue. Thus, perhaps new research is required to assess the problem and to identify the optimum box and vehicle design and practice.

Issues relating to horses

There is continuing concern over many aspects of transport of horses particularly to slaughter, where there has been little research. Although the significant number of studies on the transport of competition horses can offer some information regarding the biological responses of horses to transport (e.g. such as preferred orientation and impact of driver behaviour) these animals travel under very different circumstances to slaughter horses. In addition, the unhandled and untrained horse is likely to find all aspects of the transport process considerably more stressful than trained and handled horses. Pre-transport inspections are often inadequate and a code of practice and guidelines for this process are essential. Some attempt has been made to address this in the recently published DG SANCO Guides to Good Practice. However, some specific issues requiring further consideration including:

(1) Should transport of horses (of mixed breed and “uncertain health status”) be limited to 12 hours? There appears to be no quality research that has addressed these issues.
(2) It has been asserted that “there is a huge variation between breeds and within breeds in their thermoneutral zones” so it is difficult to define general limits. The effects of humidity have not been examined in any details in reliable publications. This area constitutes an obvious gap in knowledge and should be addressed through the appropriate research.
(3) The industry has identified benefits to diagonal placement / arrangement of horses on the vehicle and there is some published data to support this. Perhaps more comparative studies of transport stress in slaughter horses carried in different arrangements on the vehicle are merited to facilitate more sound recommendations?

Policy Recommendations

Key policy issues identified in the review exercise and welfare during transport assessments

In overall summary the data suggest that some welfare compromise is implicit in transporting animals, and opportunities to minimise journey length, duration and complexity, as well as paying attention to handling, loading and unloading procedures and driver behaviour should be adopted wherever possible. A considerable amount of work has gone into the production of the DG-SANCO 2017 guidelines for the transport of animals ['Good practices for animal transport in the EU (SANCO/2015/G3/SI2.701422) http://animaltransportguides.eu/)], and we recommend that these are disseminated and used as the basis for training and advice.

Although there are considerable gaps in knowledge in a number of areas (see Gaps in Knowledge section for details) there are also a number of areas where the scientific evidence can support policy recommendations as outlined below:

Long Journeys

Various sources indicate that it is desirable to limit all journeys by introducing a maximum journey time appropriate to species (e.g. 4, 8 or 12 hours). For example, evidence supports setting a maximum journey time of 4 hours for broiler chickens, 6-12 hours for pigs when temperatures are at or above 30□C and 18 hours when ambient temperature is lower, 12 hours for newly weaned pigs and untrained horses, 9-12 hours for calves, 12 hours for recently hatched chicks, 29 hours for cattle and 48 hours in healthy adult sheep.

Rest Periods

A pressing issue is the operational definition of the rest period that constitutes the mid-journey break in the apparent maximum journey times for each species and age of animal in EC 1/2005 and WATO 2006. Thus, currently the assumed maximum journey times for e.g. calves is assumed to be 19 hours (21 hours to final destination) comprised of a 9-1-9 hour journey i.e. with a 1 hour mid-journey break However, it is clear that the 1 hour break is actually a minimum of 1 hour and that there is no currently prescribed maximum. Thus, within the overall provision of keeping total journey time to a practical minimum and with the constraints imposed approval of journey plans by the competent authority, it is possible to extend the mid-journey break significantly and thus the overall travel time. It is recommended that this problem is addressed particularly in conjunction with any new consideration of harmonisation of driver and livestock travel times (see also Gaps in Knowledge).

If water or feed is provided during the mid-journey break then the break time must be increased, to allow animals to properly rest, eat and drink. Research suggests that animals may require prolonged periods to completely recover from the effects of transport (e.g. up to 7 days in calves or cattle). However, evidence suggests that cattle can recover substantially after 24 hours in lairage, with hay and water freely available, following long journeys. Calves require feed and water every 8-9 hours and the time required to deliver this effectively may be prolonged, particularly in animals that are not used to nipple drinkers. Evidence suggests cattle routinely drink at least every 12 hours so should be offered water during journey breaks on journeys lasting up to 29 hours. Sheep generally eat before drinking following transport, and require at least 3 hours rest to allow them to drink as well as eat, although 24 hours is required for adequate rest and drinking. However, sheep do appear to be able to withstand 34 hours food and water deprivation without significant effects on physiological parameters (or 72 hours if not transported), although dehydration will occur more rapidly at higher temperatures. Suckling lambs, however, show signs of dehydration after 5 hours without food and water. Pigs should have continuous provision of water during transport, but feeding during rest periods is problematic as mortality increases in pigs that have not been fasted prior to transport (see also Gaps in Knowledge).

The over-riding concern should be to minimise transport time (as proper recovery is unlikely to be achieved during a feasible rest period), whilst meeting the requirements of some species for food and water. Sheep and cattle that are unused to handling will find unloading and reloading stressful. Thus if adequate water can be provided on the lorry, this has suitable mechanical ventilation to prevent thermal stress, and sufficient space is available to allow the animals to lie down, then resting on the lorry would be recommended. However, for sheep and poultry there is not yet sufficient evidence for an appropriate method of supplying water on board a vehicle. There is also currently insufficient evidence in the literature to address whether markets or ferry crossings can be considered rest periods. However, the current evidence suggests that there may issues with maintenance of the thermal environment on vehicles during sea transport, and that animals may remain standing and braced during rough weather, and so be unable to rest.

Loading and handling

Cattle should be familiarised with handling and human presence in advance of journeys. This may require modification and implementation of codes of practice and new guidelines.

Space Allowance

Space allowances for sheep, cattle and pigs should be based on published allometric equations, rather than a standardised weight per floor space measure (e.g. the current maximum stocking density for pigs is presented as a single figure (235 kg m^{-2}) on an area basis and primarily applies to pigs of around 100kg body weight).

For cattle, space allowances calculated according to the allometric equation A = 0.021W0.67m^2 (where A = area and W = body weight) are satisfactory for journeys no longer than 12 hours. Cattle are given sufficient space to allow them to lie down without risk, or fear of injury when space allowances are calculated according to the equation A = 0.027W0.67 m^2. Cattle with horns require 7% more space than their polled or dehorned counterparts. Cattle offered feed and drink on a vehicle, as well as space to rest, require a space allowance calculated according to the equation $A=0.0315W2/3m^2$.

For sheep to have sufficient space to adopt their preferred spacing strategy and to reduce the incidence of loss of balance, slips and falls space allowances should be calculated as: for journeys of up to 6 hours, the recommended empirical coefficients (and space allowances) are: (i) shorn ewes, k = 0.026 (0.44 m^2 for 67 kg), (ii) fleeced ewes and lambs, k = 0.033 (0.56 m^2 for 65 kg, 0.4 m^2 for 40.5 kg), and (iii) shorn lambs, k = 0.029 (0.3 m^2 for 32.5 kg).

In the case of pigs the interaction of space allowance with ventilation and the thermal environment should be a key concern. Different space allowances are suggested for different pig groups. In general, these may be derived from the allometric equation $A=kW^{2/3}$. However, information is lacking concerning the space allowances required for good welfare of piglets, feeder pigs, sows and boars in order to validate allometric equations for different vehicles and thermal conditions (see Gaps in Knowledge).

Current recommendations for stocking densities for transport of poultry are adequate, however, these recommended stocking densities can predispose to heat stress in warm or hot weather and on long journeys and should be adjusted accordingly in response to meteorological predictions. Thus, limits for stocking densities of broilers in transport containers should be related to temperature. Numbers should be limited in conditions when external temperatures exceed the proposed acceptable range (e.g. > 22 ºC) and on long journeys (3-4 hours).

For horses it is recommended that space allowances should be given in terms of kg/m^2 instead of m^2/animal where animals are likely to differ significantly in weight or body condition. For handled horses (except for mares with foals), animals should be transported in individual pens to prevent aggression.

Head room

Head space or clearance above cattle in transit is still an issue. Current evidence suggests that, in some contexts, 20 cm clearance above the withers will reduce the incidence of carcase bruising and head butts. However, more data are required to characterise optimum practice from welfare and ventilation perspectives. There is no current evidence to support recommendations for head space requirements for sheep.

For pigs there is a recommendation that there should be 15 cm above the highest part of a pig standing in a natural position, to ensure adequate ventilation and thermal comfort. However, the optimum head space for pigs of different sizes and in different types of vehicles (e.g. passive or mechanical ventilation), is not clear.

For poultry there is conflicting welfare evidence on the impact of different head space requirements with low head room inducing stress responses and panting, and higher space inducing behavioural issues such as scrambling that may cause carcase damage.

Temperature and Ventilation (poultry)

There are no specified temperature limits for poultry transport. Therefore, it is recommended that specific thermal limits should be defined for broilers, point of lay hens and end of lay hens. Specification of thermal comfort zones for the latter two groups will require further research. From previous research it is established that the upper temperature limit in a transport container for broilers should be 24-25ºC, assuming a relative humidity of 70% or higher. The lower temperature limit for broilers in containers should be 5ºC. Localised high air velocities should be avoided on passively ventilated vehicles by close attention to curtain construction and air inlet control. Measures should be taken to prevent wetting of broilers and laying hens prior to or during transport. It is suggested that for journeys of 4 hours or over, poultry vehicles should be equipped with mechanical ventilation systems with the capacity to modify both air temperature and humidity within prescribed limits (to be defined).

In keeping with the recommendations for broiler chickens new legislation might prescribe temperature limits for newly hatched chick transport. Optimum vehicle temperatures for newly hatched chicks are currently proposed to be 24-25 ºC with limits of 22-28 ºC and container temperatures of 30-31 ºC.

Fitness to travel

For all species a proper assessment of fitness to travel is important and the animal transport guides project [‘Good practices for animal transport in the EU (SANCO/2015/G3/SI2.701422) http://animaltransportguides.eu/)] provide useful information that should be implemented. Inspection of poultry in respect of fitness to travel has long been a controversial issue and there are no new studies that better inform the issue. Appropriate training of those required to inspect poultry (and other species) is recommended, based on best practice guidance already available. For broiler chicken and transport of end of lay hens it is recommended that the existence of metabolic diseases and other possible pathologies and injuries should be considered in all aspects of handling and journey planning.

Driver behaviour/ driving style

All species are adversely affected by poor road conditions, accelerations and poor driving styles. For sheep and horses, which usually travel standing, this can be particularly severe leading to loss of balance, falls and injury. There are suggestions that these forces can be monitored via suitable accelerometers installed within the vehicle. Improved driver training and vehicle monitoring (driving) systems are recommended to minimise these risks particularly on long journeys.

For pigs, poor road conditions and vehicle suspension can increase the likelihood of motion sickness, mortality and poor welfare in transit. Better regulation of the types of vehicles used to transport pigs, especially on long journeys can help to mitigate these impacts.

ANNEXE 1

Identification of gaps in knowledge relating to the welfare of animals during transportation

In addition to the systematic and narrative review processes applied to this objective it was considered pertinent to review separately the key areas of welfare concern identified by other bodies that may or may not have been addressed by research or the development of advice or guidelines in recent years (post 2005). In terms of the content of EC 1/2005 there have been a number of reviews and expert discussion groups that have examined the areas covered in an attempt to identify either omissions or short comings in the legislation that should be examined further.

The reviews have attempted to identify those areas not adequately covered or addressed by the Regulation or to report those areas where the legislation might be usefully updated or enhanced to address specific issues of welfare concern. Thus, an expert / stakeholder group assembled by Defra in 2008 considered all the elements of the Regulation EC 1/2005 and reported (2009) on the issues arising. Also, the EFSA Opinion of 2011 (EFSA, 2011) has reported a number of areas of continuing concern that should receive attention and might have constituted future research requirements. These were presented by species (cattle, sheep, pigs, poultry and horses) and by primary welfare risk associated with specific transport factors (fitness for transport, means of transport, transport practices, watering and feeding interval, journey times and resting periods, space allowances). The outputs of the Expert Group, the EFSA Opinion (detailed and then summarised by species with appropriate references to the published Opinion) and the more recent concerns identified in the DG SANTE Guides Project are presented below. Inspection and comparison of the issues and welfare concerns identified in each publication and from each source allows assessment of progress in addressing the issues since 2005. This exercise allows also the identification of issues that may not have been resolved and which might be informed by more recent research captured by the systematic and narrative reviews. Finally if these key issues are not informed by research included in the reviews then the outstanding welfare concerns may constitute areas that should be addressed through new research i.e. they may be key gaps in knowledge.

The 3 primary sources of opinions and information are:-

(1) Stakeholder Feedback - Defra Animal Welfare Review of EU Regulations Workshop 17th November 2008 (published 20th February 2009)
(2) EFSA Opinion of 2011 (EFSA Journal 2011; 9(1):1996)
(3) Outputs of stakeholder and focus Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). ‘Good practices for animal transport in the EU: (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/)

The outputs, conclusions and highlighted areas of concern from each information source have been presented as they were published with only minor alterations for clarification of key issues and points. All the information sources have been summarised at the end of Annexe 1 and the key features, gaps in knowledge and potential future research priorities identified and highlighted

Defra Stakeholder Feedback

Below the main summary points of this workshop are presented as they were published in 2009 - (Defra Animal Welfare Review of EU Regulations Workshop, 17th November 2008, published 20th February 2009)

Ruminants

General

We recommend that Defra should realign drivers' hours and travel times and ensure ferry journeys are a rest period.

We recommend that Defra needs to maintain EU minimum regulations with regard to animal transport.

We recommend that Defra should press the EU to adopt short maximum time for slaughter journeys.

We recommend that Defra considers differing categories of journey for species and transport methods.

We recommend that Defra should highlight the situation with regard to long distance slaughter journeys.

We recommend Defra push for a consistent level of enforcement across the EU.

We recommend that Defra should consider the trade implications of legislative requirements suggested in this Regulation in order to minimise unnecessary restrictions on trade and practices.

- Four drivers per long journey possible.
- Current transport logs work here – should be properly enforced in other EU Member States.
- If transport is correct and comfortable do the journey times matter? If you have everything else right.
- Grass only grows from mid May to end August.
- Problems with lack of control posts for unloading near Dover.
- Lack of abattoirs in Scotland.
- One size does not fit all.
- Being too prescriptive may be counterproductive.
- Threat to UK industry stability and ability to trade.
- Ventilation in stationary vehicles.
- Ethnic concerns.
- UK limitations on types of abattoirs e.g. calves
- Horned animals with incorrect space allowances could cause more welfare issues.
- Sheep – different welfare and industry needs.
- Policing of rules needs to be more stringent across EU.
- Questions are not representative of the true picture.
- Species specific vehicles e.g. a problem of calves on pig vehicles – can they drink?
- Consistency across EU – no differences in interpretation.
- European conditions seem to be influencing UK movements and trade.
- Different idea of enforcement across Member States.

Journey Times

- For breeding/production animals:
    - 7-1-7-1-7-1-7 is desired.
    - No 24hr standstill because of stress and disease.
- Travel times should be aligned with driver's hours, so it's one set of times.

- Long journeys and different to short journeys.
- Times to market and collection centres.
- Should be (short) maximum time for both fattening and slaughter journeys.
- Ferry times must be neutral time not journey time.
- Differentiate between UK movements and very long continental journey times.
- Journeys from remote areas.
- Can we put a reasonable figure on the journey time for slaughter?

Resting Periods

We recommend that Defra only specify minimum rest periods of one hour and not a maximum which may cause confusion and be detrimental to welfare.

We recommend that Defra obtain clear guidance on the definition of 'rest periods' before further discussions with stakeholders.

- Rest periods must be on lorry.
- Not trying to change the rules, but want ferry time as neutral rest time.
- Animals must be able to remain on lorry during rest periods – lorries have water, feeding points – huge stress in unloading.
- Must keep rest times to one or two hours. Get rid of long rest times: e.g. 24 hours – huge stress implications.
- All classes of stock should be treated the same.
- Difference of opinion on 24 hour rest period after one cycle (slaughter v. breeding).
- Is there any evidence that lack of water during rest is detrimental e.g. markets/inappropriate equipment?
- If markets are neutral time, will water provision be compulsory (not just available) as per FVO?
- Movement of some stock classes is a necessity because of production systems.
- Need minimum rest time at rest. No maximum is required.
- Time spent in markets?

- Time in market should be rest time.
- Clear definition on what a rest period is.
- Why maximum times for mid-journey rest?
- Don't need long rest periods in transit. Aim to get animals to new home as soon as possible in proper circumstances.

Stocking Densities

We recommend that Defra should view stocking levels are very dependent on rest periods.

We recommend that all species should be transported under same rules (travelling times and densities) regardless of whether they are destined for slaughter, production or breeding.

We recommend that Defra consider there must be a level of sensitivity relating to the legislation/regulation stocking density from an enforcement perspective, i.e. driver has to take a view on any given day, with their animals.

We recommend that Defra should consider stocking densities to be the same for long and short haul journeys – providing that market time is counted as 'neutral'.

- Time of the year will be an influence on sheep transportation.
- Do we want animals to be able to lie down when being transported?
- Stocking densities:
    - Long haul/short haul.
    - Sensitivity.
- Stocking densities should be the same irrespective of journey purpose – breeding/slaughter/etc.
- Must categories journey times and rest periods to stock classes e.g. slaughter/production/breeding.

- If transport is comfortable and stocking densities are correct, do the journey times matter?

Pigs

General

We recommend that Defra considers that transport rules need to be tailored to needs of animals e.g. transport of breeding stock is different to transport to slaughter?

- Continuous access to water or only at rest of transport.
- Unloading and re-loading are the most stressful parts of the journey.
- When and where feed prior to transport after feeding – period of rest.
- The unloading of breeding pigs going into control posts is a health risk, as well as being poor welfare.
- Transport rules conflict with disease control rules – collecting centres.
- Cull sows.
- Different needs for different groups e.g. sow and litter, young stock.
- One size does not fit all.

Stocking Densities

We recommend Defra leave the stocking density at 235 kg/m^2 as there is no evidence for change.

- Should they be different for breeding or slaughter?
- Stocking rates are too simplistic – suggest a flow chart that takes all travel criteria (including weather) into consideration to arrive at correct travel conditions.
- Should feed/rest/water be taken on vehicle; if so, does this affect stocking rate?
- Size of group on lorry etc.?

- Are pigs different from other species?
- Why different stocking levels for slaughter or breeding?
- Stocking rates should be same for all journeys.
- The 2003 proposals for 40% more space when resting on a lorry would be unworkable because rest, feed and water should/can be taken on the vehicle.
- Stocking density for breeding and slaughter pigs need to be different.
- Size of group on transport.
- Stocking density can be higher for short journeys – less than 100km.

Journey Times

We recommend Defra should consider a 30 hour journey spread:

  - 1 driver – 9hrs travel/12hrs rest/9hrs travel.
  - 2 drivers – 20hrs travel/10hrs rest.

- Transport time and driver's hours should be the same.
- 100% of pigs leaving UK are for breeding.
- Should time aboard ship be part of the journey?

Resting Periods

We recommend that Defra should initiate scientific evidence to determine that time on Ro-Ro ferries could be considered rest time, as currently different interpretations on this in different EU countries – a standard approach is needed.

- Time on Ro-Ro ferries should be rest time, not neutral time.
- When pigs are on a Ro-Ro ferry they lie down for 98% of the time – scope for another Defra trial?
- Recovery times during 24 hour rest period – why 24hours?
- Previous Defra trials have shown that 10 hours is sufficient rest for pigs.
- Why 24-24-24 – is this too long?

- No mid-journey rest in 24 hours?
- Any future legislation should take into account that UK exports often utilise 2 drivers.
- Breeding pigs – unload or rest on vehicle – biosecurity issues.
- Is 24 hours too long? Drivers' hours should be close to pig travel and rest periods.

Equidae

General

- Registered horses need clear definition re: Directive 90/426.
- Mixing:
  - Registered/non-Registered equidae.
  - Movement into market.
  - Time at sea.
- Are Tripartite rules being abused?
- Partition design needs further work.

Stocking Densities

- Space allowances need to be reviewed.
- Need space:
  - floor area/height of pony.
  - mixed sizes.

Journey Times

- Finite journey limits to slaughter will cause problems in the UK.
- Time into market should count towards journey time.
- Other equidae:
  - 9-12-9.
  - 12 hours.

    - Enforcement?
- Maximum 12 hour (+2) journey time to slaughter. Derogation for journeys in EU states where a slaughterhouse cannot be reached within 12 hours.
- Avoid long distance journeys into market.
- 24- 6- 24.

Resting Periods

- Approved markets to permit rest in markets.

EFSA Opinion of 2011 (EFSA Journal 2011; 9(1):1996)

Fitness for transport

Cattle

For cattle it is considered that handling for loading and unloading constitutes a major risk to welfare in transit. As such, it is recommended that cattle receive repeated and continuous human handling during rearing in order to minimise aversive reactions at the time of transport.

Poultry

For poultry it is proposed that fitness for transport is greatly influenced by the type of bird and genetic predisposition towards metabolic disease or susceptibility to stress and/or injury. Thus it is recommended that due consideration is paid to the potential for the presence of metabolic disease and injuries in both broilers and laying hens, the effects of which may be exacerbated by hostile transportation conditions and poor handling. There should be careful inspection of both broiler chickens and laying hens prior to transport to ensure that they are fit for transport. Responsibility for such inspections must be clearly identified and defined.

Means of transport

Sheep

It is proposed that sheep are exposed in current transport vehicles to forces resulting from driving events, such as acceleration, braking, stopping, cornering, gear changes and uneven road surfaces and that these have a negative impact on the welfare of the animals. This is due to increased risk of injury and through disturbance of the ability of the animals to rest and ruminate during the journey. These events can be monitored using suitable accelerometers installed within the vehicle. Improved driver training and vehicle monitoring (driving) systems are recommended to minimise these risks particularly on long journeys.

Pigs

There is concern that pigs may be exposed to thermal stress in current forms of transport (road and air) despite apparently appropriate definitions of thermal ranges and stocking densities and environmental control. It might be proposed that control strategies and systems are not currently adequate to achieve the desired degree of control.

In addition increased drinking post-transport in pigs and evidence of dehydration may indicate that water intake of pigs while vehicles are in motion is low, despite the fact that water is provided in the vehicle.

There is a general paucity of scientific information about the handling of pigs during transport by air, such as fatigue, heat and cold stress, and fear in darkness. It has been recommended that pigs should be fasted before transport.

Water should always be available at the farm, assembly point and lairage. During long transport journeys (over 8 hours) water should be provided at rest stops. It is unnecessary to provide water continuously while the vehicle is in motion.

Poultry

It is now widely recognised that genetic selection of broiler chickens has resulted in possible predisposition to metabolic diseases and pathologies that may render these birds more susceptible to some of the stresses imposed by handling, catching and transportation. These conditions include skeletal injuries and muscle pathologies that may be exacerbated by “transport stress”. Thermal conditions in transport pose the biggest threat to bird welfare. The severity of these stresses increases with journey length. Heat stress in broiler chickens may result from elevated external temperatures, high heat and moisture production of the very large numbers of birds carried on commercial vehicles. Passive ventilation systems on many commercial poultry vehicles cannot achieve optimal temperature conditions while vehicles are both stationary and in motion. Problems of heat stress can be reduced by reducing stocking density but cannot be eliminated in the absence of mechanical ventilation systems. Cold stress may occur in end of lay hens, in broilers that are wet in cold conditions and in birds exposed to excess air movement.

Under current Regulation EC 1/2005, unlike other species of livestock there is no definition of “long journeys”. Thus, the feeding and watering intervals that impose the upper journey duration limit of 12 hours for poultry does not constitute a long journey and therefore does not require the use of higher standard vehicles. A consequence of this is that there are no specified temperature limits for poultry transport. Therefore, it is recommended that specific thermal limits should be defined for broilers, point of lay hens and end of lay hens. Specification of thermal comfort zones for the latter two groups will require further research. The upper temperature limit in a transport container for broilers should be 24-25 ºC, assuming a relative humidity of 70% or higher. The lower temperature limit for broilers in containers should be 5 ºC. Localised high air velocities should be avoided on passively ventilated vehicles by close attention to curtain construction and air inlet control. Measures should be taken to prevent wetting of broilers and laying hens prior to or during transport. For journeys of 4 hours or over, poultry vehicles should be equipped with mechanical ventilation systems with the capacity to modify both air temperature and humidity within prescribed limits.

Horses

As most horses transported are not accustomed to living as a social group then horses should be transported in individual pens to minimise the risk of aggression. In addition as horses appear to be more susceptible to postural instability in transit due to imposed accelerations and forces (compared to other species of livestock when transported) then the partitions used between individual stalls should protect and isolate (physically and socially) each animal but should not impair ventilation within a load. Horses rely on sweating during exposure to elevated temperatures so air movement within a stall must be optimal. The only exceptions to individual stalls or pens are for mares travelling with their foals and groups of semi-feral, unbroken ponies already accustomed to living as a social group. The current maximum group size of 4 allowed for this type of pony under EU legislation appears to be the optimum. Perhaps more work is required to define acceptable partition design for equid animals, especially to avoid overheating, and this needs to be determined in conjunction with acceptable stall/pen materials, dimensions and orientation to also avoid physical damage.

Transport practices

Loading, unloading and handling

Cattle

It is recommended that cattle trucks should be partitioned to facilitate better and easier loading. Partitioning of vehicles for cattle reduces the risk of injury, allows faster loading and unloading and allows animals to settle better during transport and thereafter at lairage. Thus, cattle should be transported in vehicles fitted with partitions so that the animals can be transported, loaded and unloaded in small groups.

Pigs

Handling during loading and unloading of pigs is associated with stress and the exacerbation of aggression and associated risk of injury. Handling procedures should therefore be modified to take account of these risks. Groups of animals should be kept stable and limited to 6 pigs during loading. Sows and boars should be handled separately and transported in separate compartments. 'Birth to slaughter' systems, where litters of pigs are kept together from birth to slaughter, including transport and pre-slaughter lairage, are recommended.

During transport

Pigs

There appears to be a lack of published information on the effects of ventilation and environmental control on the welfare of pigs in transit. Mechanical ventilation is suitable for cooling pigs in vehicles in most circumstances provided that it has adequate capacity. In conditions when it is inadequate to prevent heat stress, additional measures, such as sprinklers or air-conditioning, can be used to cool pigs.

Fan-assisted ventilation should have adequate capacity to ensure thermal comfort. The capacity of fan assisted ventilation should be determined under different thermal conditions. Research is required to characterise the effects of mechanical ventilation and air conditioning or other cooling systems on the well being and health of transported pigs of different ages (weaner piglets, fat pigs, cull sows and boars).

Poultry

The available evidence suggests that journey times and space allowances for newly hatched chicks are adequate. However, it is well recognised that newly hatched chicks are particularly vulnerable to cold stress in transport but current industry practices and internal controls ensure that the risk of cold stress is minimised.

Heat stress in chicks will increase the rate of depletion of water and energy reserves and will pose an immediate risk to welfare and a long term risk to productivity. Optimum vehicle temperatures for newly hatched chicks are currently proposed to be 24-25 ºC with limits of 22-28 ºC and container temperatures of 30-31 ºC. There is no new evidence to suggest that these definitions or limits should be changed. Adequate ventilation of chick vehicles and transport containers is vital to maintain welfare in transport. It is suggested that additional research might better characterise the ventilation of transport containers for newly hatched chicks and might examine the impact of different box designs and stocking densities or space allowances to further improve environmental control and chick health and welfare in transit.

It has been considered that the utilisation of yolk sac substrates and reserves in newly hatched chicks from modern commercial broiler lines might impact upon acceptable journey times for newly hatched chicks. Review of all the available evidence suggests that this may not be the case and current journey limits are adequate to protect the chicks.

Watering and feeding interval, journey times and resting periods

Cattle

Published work indicates that for cattle, journeys of 12 to 24 hours will lead to fatigue and the physiological changes reported may take 24 hours or longer to return to normal levels, depending on the category of animal and feeding regime during the recovery period. After transport of 29 hours heifers show significant signs of fatigue. Bulls kept in lairage for 24 hours after transport of 25-29 hours show significant signs of muscular fatigue.

It is recommended that during journeys of 8 to 29 hours, cattle should be offered water during rest periods. This is especially important in hot conditions. Adult cattle should not be transported on a journey of longer than 29 hours, even when ventilation is good and space allowance adequate. After this time there should be a 24 hour recovery period with access to appropriate food and water. Only limited published information is available on optimal thermal environments and journey times for young calves, optimal feeding and watering of calves in transit and rest periods for adult cattle.

Sheep

Research has demonstrated that healthy adult sheep, transported under good conditions can tolerate transport durations and associated feed and water withdrawal periods of up to 48 hours without undue compromise to their welfare. However, exposure to heat stress increases water loss principally through thermal panting and this increases the risk of significant dehydration. Some concerns have been identified in that sheep may not drink water from unfamiliar sources in novel environments. However, provision of a 24 hour rest stop is sufficient to ensure adequate drinking and rest. Sheep that experience dehydration during a journey may be less able to respond effectively to other environmental challenges such as an increase in environmental temperature during a journey. It is reported that off-trailer rest stops with feed and water during long distance transport at high ambient temperatures eliminated signs of food deprivation and dehydration but did not alleviate transport stress and evidence of immunosuppression.

Off-loading can increase the stress associated with handling, loading, unloading, and possibly social changes, after exposing the animals to another novel environment.

Pigs

The available information suggests that **8** hours of rest allows pigs to regain some weight due to rehydration. Although length of transport is usually considered a major risk factor for the welfare of pigs, other hazards attributable to vehicle design (e.g. drinkers, suspension), driving style, stocking density and inadequate ventilation may cause greater stresses whatever the length of the journey.

Short and long transport periods may have the same effect on the stress level and physical fatigue in weaned piglets. Weaners may show different stress responses to transport from those seen in older pigs. In relation to journey duration, mortality increased when the pigs had not been fasted before the journey, but that duration had little effect when the pigs had been fasted, even for journeys lasting 24 hours. It is recommended that for journeys exceeding 24 hours feed should be available every 24 hours at staging points followed by 6 hours rest.

It is proposed that there is a clear paucity of data and information relating to the transportation of young pigs including weaners. The optimal journey time for weaners should be further investigated and optimal watering intervals should be defined. Thermal comfort for weaner pigs should be characterised.

Poultry

Research has clearly demonstrated the importance of temperature-humidity combinations in determining the welfare of poultry in transit and thus journey duration or period of exposure will have a significant effect upon the welfare outcomes of transportation. "Thermal load" multiplied by journey duration is an important determinant for deaths in transport resulting from thermal stress. Thus, journeys of over 4 hours for broiler chickens and end of lay hens constitute a greater risk to welfare from thermal stress (heat or cold) than shorter journeys, particularly in more severe weather conditions. Therefore, journey times should be minimal and before a journey is undertaken the weather conditions should be taken into account.

It is recommended that for journeys longer than 4 hours for broilers and end of lay hens, vehicles should be equipped with mechanical ventilation with the capacity to maintain satisfactory thermal environments. The thermal environment within the transport space should be monitored and recorded. An alarm system should be installed to notify the driver in the event of conditions predisposing to heat or cold stress. At present the journey times for poultry are equivalent to "wheels turning time" i.e. the period between leaving the farm and arriving at the destination. Perhaps for consistency journey time should include loading and unloading, and standing periods.

Horses

Some published findings indicate that an hour is an adequate time for a water stop to allow most of the horses to drink at least once. However, there was a trend for horses even with proper access to water during transport to lose weight, indicating that they do not consume an adequate amount of water and therefore are likely to become severely dehydrated after journeys lasting 18-20 hours.

The effects of transport on horses are profoundly influenced by their previous experience of transport and their state of health before transport. There is evidence of increased pyrexia in horses transported for 10 hours and immunosuppression in horses transported for 12 hours. There was a large increase in clinical signs of acute respiratory disease in horses transported for slaughter after road journeys in excess of 12 hours. On the basis of the available evidence it is suggested that when untrained horses of uncertain health status are transported for slaughter, the journey time should not normally exceed 12 hours.

At least one hour should be allowed during the watering stop to allow animals to drink and, if necessary, feed. During the whole of any rest period all horses should have continual access to an unrestricted supply of clean drinking water. All horses should have continual access to an unrestricted supply of clean drinking water for a period of one hour before transport and for one hour immediately following transport.

Space allowances

Cattle

The calculation of space allowances (stocking density) for animals in transit is complex and has received a great deal of attention. The allometric basis for determination of space allowance has been the subject of extensive debate. For cattle, space allowances calculated according to the allometric equation $A = 0.021W0.67m^2$ (where A = area and W = body weight) are satisfactory for journeys no longer than 12 hours. Cattle are given sufficient space to allow them to lie down without risk, or fear of injury when space allowances are calculated according to the equation $A = 0.027W0.67\ m^2$. Cattle with horns require 7% more space than their polled or dehorned counterparts. Cattle offered feed and drink on a vehicle, as well as space to rest, require a space allowance calculated according to the equation $A=0.0315W2/3m^2$.

It is reported that bruising injuries are significantly increased when the ceiling of the compartment is less than 20 cm above the withers height. Thus, it is proposed that cattle should be provided with sufficient space to stand without contact with their neighbours and to lie down if the journey is more than 12 hours. The equations that allow for this are $A = 0.021W0.67\ m^2$ for journeys of up to 12 hours and $A = 0.027W0.67\ m^2$ for journeys of over 12 hours. For cattle with horns, the space allowance should be 7% higher. If cattle are to be offered feed and drink on a vehicle as well as space to rest, space allowances should be calculated according to the equation $A=0.0315W2/3m^2$. Ceiling height should be at least 20 cm above the withers height of the tallest animal.

Sheep

It is reported that the minimum space allowances given in EC Regulation 1/2005 do not allow sheep to adopt their preferred spacing strategy and this leads to greater loss of balance, slips and falls. The allometric equations of the form $A = kW^{2/3}$, where A is the area in m^2, k is a constant and W is the liveweight in kg, can be used to estimate the space an animal occupies as a consequence of its mass. The value of the constant k will be determined by the spacing strategy of the sheep, whether they want to lie in transport, and whether all animals need to lie at the same time.

It was therefore recommended that space allowances for sheep should be based on allometric equations relating size to body weight. For journeys of up to 6 hours, the recommended empirical coefficients (and space allowances) are: (i) shorn ewes, k = 0.026 (0.44 m^2 for 67 kg), (ii) fleeced ewes and lambs, k = 0.033 (0.56 m^2 for 65 kg, 0.4 m^2 for 40.5 kg), and (iii) shorn lambs, k = 0.029 (0.3 m^2 for 32.5 kg).

Pigs

In the case of pigs it is suggested that the interaction of space allowance with ventilation and the thermal environment should be a key concern. Different space allowances are suggested for different pig groups. In general, these may be derived from the allometric equation $A=kW^{2/3}$. Information is lacking concerning the space allowances required for good welfare of piglets, feeder pigs, sows and boars in order to validate allometric equations for different vehicles and thermal conditions.

Poultry

It is considered that current recommendations for stocking densities for transport of poultry are adequate, however, these recommended stocking densities can predispose to heat stress in warm or hot weather and on long journeys and should be adjusted accordingly in response to meteorological predictions. Thus, limits for stocking densities of broilers in transport containers should be related to temperature. Numbers should be limited in conditions when external temperatures exceed the proposed acceptable range (e.g. > 22 ºC) and on long journeys (3-4 hours).

Horses

It has been reported that horse welfare during transport is poorly associated with stocking density when it is defined in terms of m^2/animal. There is a much stronger relationship with stocking density when it is defined in terms of m^2/kg. This is particularly important when animals are transported in groups of heterogeneous weight or are of heterogeneous body condition. It was recommended that space allowances should be given in terms of kg/m^2 instead of m^2/animal where animals are likely to differ significantly in weight or body condition.

SUMMARY OF MAIN EFSA RECOMMENDATIONS PUBLISHED JANUARY 2011

Cattle

- There should be repeated human handling during rearing and immediately prior to transport, in order to minimise aversive (sic) reactions at the time of transport. *[conclusion/recommendation p 85, brief background at paragraph 2.5.1 on page 43]*
- Journey time limit for adult cattle no longer than 29 hours (as at present). After this time there should be a 24 hour recovery period with access to appropriate food and water. *[conclusion/recommendations p 99, background para 2.5.4.4 on p 48-49].*
- Should be offered water during rest periods on journeys of 8 to 29 hours as mature cattle drink at least every 12 hours and lactating animals more frequently . *[conclusion/recommendation p 99, background last paragraph of 2.5.4.4 on p 49.]*
- Should have sufficient space to stand without contact with their neighbours and to lie down if the journey is more than 12 hours. Additional space should be allowed if the cattle are to be fed and watered on board. *[conclusion/re*commendation *p104-105, background see "space allowance" on p 45-47.*
- Recommended space allowances per animal are provided for under and over 12 hour journeys (shown as standing and lying) calculated by using allometric equations that relate body volume to mass. The allowances arrived at 'are roughly equivalent to current 1/2005 allowances'. *[conclusion/ recommendation p 104-105, background (including table) p 46-47]*.
- Space allowance for cattle with horns should then be 7% higher. *[conclusion/recommendation p 104-105, background penultimate paragraph p47].*
- 20cm headroom above withers of tallest animal for cattle standing during journeys. [*conclusion/recommendation p 104-105, background p47-48]*

- Should be transported in vehicles fitted with partitions to enable transport, loading and unloading in small groups. [*conclusion/recommendation p 94, background p45]*
- Ventilation in vessels transporting cattle should have capacity to prevent excessive heat load, using mechanical ventilation if necessary; and electrolyte solutions made available on long journeys to reduce heat stress. *[conclusion/recommendation p 89, background p43-44]*

Sheep

- Driving quality on long journeys should be monitored and recorded using accelerometers in the vehicles to monitor and help avoid excessive acceleration, braking, stopping, cornering, gear changing and uneven road surfaces. *[conclusions/recommendations p 87-88, background p32-33]*
- Suggested space allowances per animal provided which are calculated by using allometric equations that relate body volume to mass. *[conclusion/recommendation p106, background p34-35]*.
- Healthy sheep in good conditions can tolerate transport durations and associated feed /water withdrawal periods up to 48 hours; *[conclusions (no/recommendations) p99, background p35-39]*.
- Sheep may not drink from unfamiliar sources novel sources but a 24 rest is sufficient to ensure adequate drinking and rest. *[conclusions (no/recommendations) p99, background p35-39]*.
- Sheep experiencing dehydration may be less able to respond to environmental challenges such as temperature increases during a journey;
- Off trailer breaks at high temperatures do not alleviate transport stress; off loading can increase stress associated with handling, loading, unloading and possibly social changes. *[conclusions (no/recommendations) p99, background p35-39]*.

Pigs

- Should be fasted six hours before transport and water should always be available at the farm, assembly point and lairage. During long transport journeys (over 8 hours) water should be provided at rest stops but it is unnecessary to provide water continuously while the vehicle is in motion as per 1/2005 at present. *[conclusion/recommendation p 87, background p25 and 28-29]*
- Should be loaded onto vehicles in groups of no more than six. *[conclusion/recommendation p 94, background p27]*
- Sows and boars should be handled separately and transported in separate compartments. *[conclusion/recommendation p 94, background p27]*
- On journeys exceeding 24 hours, feed should be available every 24 hours at control posts, followed by 6 hours rest. But report says it is not possible to recommend an optimal journey time as it seems the conditions of transport are what matter. In the absence of any explanation the 6 hours after feeding at a control post is taken to mean do not feed less than 6 hours before resuming the journey. *[conclusion/recommendation p98-99, background p28-29]*
- Possible space allowances are given but insufficient data to say whether they give enough space for on-board access to feed and drink and different groups of pigs may need different allowances. Suggested space allowances per animal are calculated by using allometric equations that relate body volume to mass. *[conclusion p107 , background (including table) p 31-32]*

Poultry

- Careful inspection of both broiler chickens and laying hens prior to transport to reduce incidences of the birds being transported with metabolic disease, pre/existing pathologies, old or new injuries and transport in poor conditions. *[conclusion/recommendation p85, background p58-60]*.
- Specific thermal limits should be defined for broilers, point of lay hens and end of lay hens .Temperature envelope of 5-24/25C for broilers assuming a relative

humidity of 70% or higher. *[conclusion/recommendation p88, background p61-65].*

- Localised high air velocities should be avoided on passively ventilated vehicles by close attention to curtain construction and air inlet control. Presumably less than 4 hours. *[conclusion/recommendation p88, background p64].*
- Vehicles used for journeys of 4 hours or more should have mechanical ventilation systems and the temperature should be monitored and controlled. Journey time should include loading and unloading and standing periods. *[conclusion/recommendation p88 and 100, background p64-65].*
- Measure should be taken to prevent wetting of broilers and laying hens before and during transport. *[conclusion/recommendation p88, background p 63].*
- Temperature limits for newly hatched chicks during transportation should be introduced within range 22-28C, 30-31C in containers. Adequate ventilation vital. *[conclusion/recommendation p96, background p66-69].*
- No changes in space allowances recommended but should limit densities of broilers in transport containers when external temperatures exceed 22C and on long journeys. *[conclusion/recommendation p108, background p66].*

Equidae

- Should always be transported in individual stalls or pens, whether by road, rail, air or sea (other than mares with foals at foot and unbroken Equidae). [*conclusion/recommendation p 86-87, background p15-16]*
- Partitions should protect and physically/socially isolate each Equidae, as they find it relatively difficult to maintain their posture during sudden vehicle movements, but not impair ventilation [*conclusion/recommendation p 86-87, background p15-16].*
- Time horses spend on a lorry loaded onto a vessel should not be considered as a resting period but as journey time. N.B. this is not mentioned in relation to other species. *[conclusion/recommendation p89, background see 2.1.2.2 on p16].*

- Journey time for untrained horses of 'uncertain health status' for slaughter should not normally exceed 12 hours. N.B. This wording does not say all slaughter horses. [*conclusion/recommendation p 98, background to journey times p19-21]*.
- At least 1 hour for watering stops to drink and if necessary feed. *[conclusion/recommendation p 98, background see "Water" on p19 "water supply on p 22]*
- Continual access to an 'unrestricted' supply of clean drinking water for a period of one hour before transport and for one hour immediately following transport. *[conclusion/recommendation p 98]*
- Space allowances should in terms of kg/m^2 instead of m^2/animal where animals are likely to differ significantly in weight or body condition. *[conclusion/recommendation p 86-87, background p23-25]*
- Groups of 4 unbroken equidae 'about right'. *[conclusion/recommendation p 86-87, background p18-19]*

HAZARDS BASED ON EXPERT OPINION WITH HIGHEST IMPACT ON THE WELFARE OF ANIMALS DURING TRANSPORT

EFSA Opinion of 2011 (EFSA Journal 2011; 9(1):1996)

For each of the farm animal species, experts from the working group were asked to consider a wide range of hazards and their impact on the risk of poor welfare during transport. The hazards were categorised in order of impact on animal welfare and those most highly ranked are listed by species below.

Cattle

Inadequate inspection prior to transport; failure to detect injury and latent disease;

Inadequate vehicle design; especially inadequate ventilation, slippery floors, lack of partitions, resulting in heat stress, injuries and exhaustion;

Inadequate loading facilities (driveways, ramps and gates) resulting in fear and injury;

Inadequate planning and execution of long journeys, resulting in heat stress, dehydration and exhaustion;

Erratic driving, causing exhaustion and injuries

All of these hazards may cause death, severe stress and disease and thus constitute major welfare concerns.

Journey length and exacerbation of journey length by poor driving and/or road/sea conditions resulting in disease, injury and exhaustion

Sheep

Inadequate floor space resulting in exhaustion and injury, and increasing risk of heat stress when sheep are transported at high ambient temperatures;

Inadequate ventilation, resulting in heat stress when sheep are transported at high ambient temperatures, especially when the vehicle is stationary;

Slippery floors combined with erratic driving resulting in fear, exhaustion and injuries.

Pigs

Inadequate natural and mechanical ventilation when the vehicle is stationary resulting in heat stress when ambient temperature is high. The problem is exacerbated when stocking density is at the maximum prescribed limit;

Inadequate planning of the journey leading to prolonged journey times causing exhaustion;

Prolonged restriction of water before transport, resulting in dehydration and heat stress when slaughter pigs are transported at high ambient temperatures or cold stress in weaner pigs transported at low ambient temperatures;

Prolonged fasting before transport, resulting in exhaustion and cold stress

Poultry

Broiler chickens

The presence of existing injuries and disease exacerbated by poor catching and handling;

Exposure to heat or cold stress in transport containers due to poorly controlled passive ventilation regimes (low or excessive local air flows);

The risk of cold stress will be increased if birds are wetted prior to or during transport.

End of lay hens

Presence of existing injuries and disease, particularly skeletal injuries exacerbated by poor depopulation and handling;

Exposure to heat or cold stress in transport containers due to poorly controlled passive ventilation regimes (low or excessive local air flows);

The risk of cold stress will be increased if birds are wetted prior to or during transport or when stocking densities are low and hens poorly feathered.

Newly hatched chicks

Exposure to heat or cold stress in transport containers due to poorly controlled ventilation regimes of “chick boxes” (low or excessive local air flows);

The risk of cold stress will be increased if chick space allowance is high or bird numbers small;

Hypothermia is the major risk to this category of birds.

Horses

Poor inspection of equid animals prior to transport resulting in the transport of animals diseased, injured and otherwise unfit to travel;

Lack of appropriate individual penning resulting in aggression between conspecifics, injury and exhaustion;

Lack of appropriate penning resulting in reduced ventilation leading to heat stress, exhaustion and disease;

Lack of appropriate penning leading to inability to balance or maintain posture resulting in injury, exhaustion and disease;

Lack of appropriate penning causing direct physical injury and exhaustion;

Poor watering provision at all stages in the transport process resulting in dehydration, heat stress and exhaustion;

Outputs of stakeholder and focus Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017).

'Good practices for animal transport in the EU (SANCO/2015/G3/SI2.701422) http://animaltransportguides.eu/)

Cattle

1. The long journey transport of calves and the problems associated with the provision of feed/water (particularly where milk or milk substitute is the preferable option) to calves on vehicles (drinkers/nipples, troughs etc.) is controversial. Concomitantly, the long journey transport of unweaned calves was considered as a controversial issue for some stakeholders.
2. Some other points were raised after the first reviewing of the draft: the height of the deck, the space allowance in particular for rest, the amount of water provision, the use of electric prods for calves, etc.

Main views

1. Regarding the long journeys of calves, the issue is not new and is well known for several years. From the NGO's point of view, long journeys of unweaned calves should be banned because of inadequate watering system in most of the trucks and because of the impossibility to control quality and amount of water or liquid feed delivered to the animals during the transport and the break. From the industry point of view, feeding the animals during the resting period is not the preferred option because of higher risk for the health and welfare of animals and most of the operators consider that it is better to not give to the animals any liquid when transport is shorter than 19 hours. However, there is a consensus on the possibility to feed individually the animals and to control the amount of liquid feed per calves in high quality control post during very long journeys (more than 19 hours).

2. Regarding the height of deck, the space allowance, the amount of water and the use of electric prods, the main views were expressed using different sources of information (for instance, EFSA reports, other legislation, etc.) or the specific experience of the different stakeholders. Opinions diverge between NGOs, scientists and industry, but also between the representatives of each category.

Solutions

1. Regarding the long journeys of calves, some transporters gave the example of calves fed individually in control posts after 9 hours of transport followed by a few hours of rest. Based on this example and considering that, so far, there is not sufficient data available to consider this operating procedure as a good practice, it was decided to insert this example as a “better practice” and to underline the fact, that transport of unweaned calves over more than 9 hours is not recommended.
2. Regarding the other controversial points, in most cases, the compromise was reached by adhering directly to the Regulation (EC) 1/2005.

Sheep

1. Fasting period. Among the stakeholders there were different welfare arguments in favour of or against fasting.
2. Space allowances for categories of sheep were considered insufficient to base recommendations on. The Focus Group agreed to use allometric equations, based on animal weight.

Main views

1. Regarding the fasting period, transport companies and veterinarians were in favour of fasting period, while NGO were against. Arguments in favor of fasting period are that it helps to reduce the amount of faeces passed during the journey. An

appropriate fasting time is important to reduce the respiratory distress of animals during the journey and the fecal contamination of carcasses during the slaughter operations. NGOs argued that a too long fasting will result in hunger and defects on meat quality (DFD, dry firm and dark meat).

2. Regarding space allowance, a NGO took the initiative for changing the recommendation of space allowance using allometric equations as EFSA 2011 recommended instead m^2/animal. The other stakeholders agreed with that statement as they think that legislation was not practical in this point. Sheep scientific experts consider that sheep and lambs categories for space allowances are not clear in legislation. Differentiation between sheep and lambs is much more complex than simply considering only their body weight and experts think that a definition for sheep and lamb should be necessary in Regulation (EC) No 1/2005. However, they think that it would be more useful to use allometric equations taking into account EFSA suggestions. Allometric equations should permit adapting the space allowances values according to the temperature and sheep category.

   In fact, in Spain and Italy, depending of the region, a lamb can have 12 kg or 35 kg body weight when going to the slaughterhouse. In addition, it is not the same in summer in the Southern countries, when enough space is basic for a good thermoregulation, than in winter in northern areas, where provide close social contact between animals is essential.

Solution

1. Regarding fasting period, the sheep focus group has reached consensus by writing two best practices in the guide.

Pigs

1. Responsibility of people involved in pig transport for the pig fitness to travel has been questioned by the stakeholders; this point has been analysed from diverse angles in relation to the tasks and roles of factors of the transport process.
2. Access to the truck compartment should be provided to allow pigs to be inspected and cared for. This has been discussed carefully: should the access be physically into the compartment (which is dangerous!), or should it be a 'visual access' only allowing drivers and/or attendants to decide on what action to take?
3. Head space allowance in the compartments was under discussion in relation to the pig needs of movement and ventilation.

Main views

1. Some representatives of pig farmers and transporters in the stakeholder group shared the opinion that pig fitness to transport should only be assessed by a veterinarian before the journey starts being the only responsible person for deciding the pig fitness to travel. NGOs and competent authority raised the point that further checks of pig fitness also should be carried out later on at loadings and at stops during the journey so that not only vets, but also farmers, keepers, handlers and drivers should be skilled, informed, trained and responsible for the fitness of pig to travel at each stage of the transport process.
2. Representatives of NGOs for animal protection pointed out that the means of transport, containers and their fittings, in a number of cases, are not designed, constructed, maintained and operated in order to provide access to the animals and to allow them to be inspected and cared for according to legislation. A discussion was held about how this access could be performed by means of physical access into the compartment, or only 'visual access' allowing drivers to decide on what action to take? Representatives of transporters and vehicle constructors pointed out that access gates for pig compartments are usually in place, although they are rather small to allow physical access, because of the limited heights of the compartments in use. These are not practicable and safe for drivers and attendants to enter the truck compartment to inspect and care pig individually. In case of a need for such a kind of intervention stops should

be carried out at control posts or at suitable facilities where pigs can be unloaded, handled and inspected individually.

3. NGOs complained about the lack in the truck of compartments of sufficient space to ensure adequate ventilation above the pigs when they are in a naturally standing position, without taking account natural movement as required by Regulation (EC) 1/2005; at least 15 cm of space above the highest point of the highest pig has been suggested by DG Sanco (on September, 4th, 2009) and recommended in the report of the Scientific Committee on Animal Health and Animal Welfare "The welfare of animals during transport", adopted on 11 March 2002. Representatives of transporters, vehicle constructors and pig farmers objected that the implementation of this practice would result in a lower number of pigs transported per truck and higher costs of transportation per pig; moreover, there is no evidence of this recommendation put in practice by any transport company so that it cannot be considered as a good practice per definition because not practiced by anybody. However, all stakeholders shared the opinion that deck minimum heights according to the pig size and live weights should be included in the guideline as a reference.

Solutions

1. Finally, all stakeholders accepted to indicate keepers, drivers and veterinarians as responsible for the pig fitness to travel.
2. After the end of the discussion the good practice proposed by an NGO for mandatory access doors to allow drivers and attendants to have physical access to pigs into the compartments was not accepted because not agreed by 100% of the stakeholders.
3. At the end a table with recommended heights of the decks, according to five categories of pig size and live weight was agreed by all stakeholders and included in the guide.

Poultry

1. The catching and carrying of poultry in the shed has been debated. A compromise was found by preparing a fact sheet shared by all stakeholder groups.
2. Visual inspection was not considered possible. The group compromised by stressing that "what is possible, should be done"
3. Headspace and water delivery to birds during transport
4. Animal Based Measures: some poultry focus group members considered ABMs not applicable during transport

Main views

1. Birds should be supported by the second hand of the catcher under the breast, so that not all the weight was placed on their legs when handled upside down. In other words, a catcher can catch birds with one hand, but not with his second hand. This hand has to be kept free to support the group hanging in his other hand. This position was supported in particular by the NGOs. After a debate also the representatives of industry accepted this approach.

2. Everyone agreed that currently many crates and containers are built without the possibility to access the birds inside (to upright them or humanely kill them if seriously injured during transport, for example) but that ideally one should be able to access them and the law does require "access to the animals during transport". Making containers with access doors for broilers and making laying hen crates with side-access doors is fully feasible.

3. Everyone agreed that providing birds with too much headspace could cause them to smother each other, but according to NGOs and industry enough headspace is still necessary to guarantee good air flow and allow them to move a little bit. Everyone agreed that the so-called water nipple system was not effective in practice because not all birds could stand up adequately to actually walk towards the individual nipple per crate.

4. Industry representatives in the poultry focus group were not convinced of the practical use of animal based parameters to measure animal welfare of birds. NGOs insisted on the feasibility and usefulness of animal based parameters.

Solution

1. A compromise was found by producing a fact sheet about catching birds
2. A compromise about visual inspection was reached by stressing that "what is possible, should be done"
3. Everyone agreed that the so-called water nipple system was not effective in practice, because not all birds could stand up adequately to actually walk towards the individual nipple per crate.
4. Animal based parameters have been included as optional

Horses

The guide focuses on horses for slaughter, but transport of horses for all other purpose needs attention. Compared to the other species, this is a very important part of all transport journeys, and often such transport is carried out by non-professionals. Moreover, at the end of their career, sports and leisure horses usually are slaughtered. There was a lot of discussion on exemptions in Regulation 1/2005 for Registered horses, e.g. regarding the need for a journey log, navigation system, watering and feeding intervals and journey times. These exemptions are open to abuse, but particularly raise the question why horses are treated differently depending on their designation. Some focus group members have experienced that it is not necessarily the case that registered horses are in a good condition, well cared for and transported in higher standard vehicles. Moreover, competent authorities usually only check consignments for which documentation is submitted and are generally not aware of illegal movements.

Some initially recommended practices that were formulated were very specific (e.g. recommended space on each side of the animal, strict temperature ranges) and were criticised. Only some experts had experience with diagonal placement of horses, therefore the benefits were questioned. Finally, the type of bedding material was discussed.

Main views

1. There is a huge variation between breeds and within breeds in their thermoneutral zones, so a very specific guideline is not practical. The same is true for space requirements, and both too much and too little space have a negative impact on animal welfare. Too much space can cause balancing problems. Therefore, some experts stated that there should be room for expertise as there are numerous factors that affect the impact of low or high temperature on animal welfare or space requirements. Transporters should be able to take these into account since they are trained and experienced. The decision whether animals should be put in separate stalls or not is also a matter of expertise for which no strict guideline can be formulated.

2. The experts that had experience with diagonal placement were very enthusiastic about it and the truck manufacturer in the duo group showed examples of truck where this can easily be applied.

3. The type of bedding can vary between geographic regions. Some experts favoured wood shavings, where others preferred chopped straw.

Solutions

1. Regarding the transport of end of career registered horses, focus group members have contacted national competent authorities and the Commission with the request to look into this further. Practices in the guide are formulated as specific as possible. The use of targeted animal based parameters has been suggested to monitor animal welfare and to provide provisions in trucks to adjust space per animal.

2. Diagonal placement is mentioned as a recommended practice, and can be applied by those who have vehicles that allow it.
3. It was agreed that the material should absorb moisture and be dust free, and that the final choice can depend on availability and cost of material.

SUMMARY – Gaps in Knowledge

Key issues and concerns identified in previous review exercise and welfare during transport assessments

One of the priority areas identified in the previous review processes has been the disparity in the social regulations relating to drivers hours and the journey times presented for livestock in current regulations (e.g. EC 1/2005). For all livestock species on long journeys it is clear that this disparity leads to problems of scheduling or causes some economic pressure by requiring 2 drivers for some types of long journey. The definition of rest periods as they relate to drivers rest periods requires attention. Harmonisation of the driving regulations with animal welfare in transport regulations is desirable but there is no research to determine if the various proposed travel time combinations that would facilitate harmonisation have any positive or negative impacts on animal welfare. It may be proposed that this issue is a key research requirement.

Another important area is the consideration of long journeys to slaughter i.e. journey of over 8 hours duration (or 12 hours in the UK). It is recommended that journeys are considered in relation to the current legislation i.e. are categorised as standard or long and that the term export for slaughter is not used to denote long journeys (i.e. an export journey may be standard or anon-export journey to slaughter may be long!). Various sources indicate that it may be desirable to limit all slaughter journeys by introducing a maximum journey time appropriate to species (e.g. 4, 8 or 12 hours). It is proposed that all the necessary science / research is in place to support such recommendations and whilst action may be required no further research requirements can be identified.

For long journeys from the UK (regardless of purpose) there are a number of concerns that should be addressed. Firstly, how time on board a ferry is designated and whether the rest on-board ship is to be rest time, neutral time or part of journey time. The industry suggests that final clarification of these issues is essential. Whilst this specific issue is not really amenable to the provision of a solution through research another aspect of ferry transportation requires further examination. The thermal environment during ferry transport is poorly understood as there a very few publications in the field. It is proposed that research is required to better understand optimum ventilation strategies for vehicles on-board ferries. The limited publications indicate that there are key differences between passive and mechanical ventilation regimes on stationary vehicles on ferries and this topic requires further elucidation.

Another general area requiring examination is the time spent in markets and whether and how animals of different livestock species should be fed and watered during this period. There is only limited published information available pertaining to these issues. The better definition of time is markets and what might be required to optimise welfare in relation to the entire "legal" journey is a priority. No new research is available concerning time in markets.

A pressing issue is the operational definition of the rest period that constitutes the mid-journey break in the apparent maximum journey times for each species and age of animal in EC 1/2005 and WATO 2006. Thus, currently the assumed maximum journey times for e.g. calves is assumed to be 19 hours (21 hours to final destination) comprised of a 9-1-9 hour journey i.e. with a 1 hour mid-journey break However, it is clear that the 1 hour break is actually a minimum of 1 hour and that there is no currently prescribed maximum. Thus, within the overall provision of keeping total journey time to a practical minimum and with the constraints imposed approval of journey plans by the competent authority, it is possible to extend the mid-journey break significantly and thus the overall travel time. It is recommended that this problem is addressed particularly in conjunction with any new consideration of harmonisation of driver and livestock travel times. Of course, if other recommendations are implemented such as the provision of water or feed during the mid-journey break then the break time must be increased. It has been proposed that on journeys of up to 29 hours for cattle water should be provided in the break. These problems may not require further research but are an important consideration in proposed re-examination or amendment of current policy, codes of practice or legislation.

Another key area is the application of temperature limits to all animals of one species regardless of age or physiological status. This is clearly inappropriate as calves and piglets will require very different thermal micro-environments to more mature animals. Surprisingly the systematic review did not identify published research of high quality that might inform the proposal of appropriate temperature regimes for animals of different ages / maturity with differing thermoregulatory capacities. New research to address the definitions of temperature limits for piglet and calves might constitute a future research priority.

Issues relating to cattle and calves

Previous review exercises have identified a number of key issues:-

(3) Cattle should be familiarised with handling and human presence in advance of journeys. This may require modification and implementation of codes of practice and new guidelines bit should not require further research as the evidence is available.

(4) Evidence suggests cattle routinely drink at least every 12 hours so should be offered water (se above) during journey breaks on journeys lasting up to 29 hours. No further research required.

(5) Cattle should have sufficient space to stand and lie down on long journeys and more space may be required is they are to be fed and watered on-board.

(6) Space allowances should be based on published allometric equations and modified according to needs i.e. for feeding / watering access or carriage of horned animals (+7%)

(7) Head space or clearance above cattle in transit is still an issue and perhaps more data are required to characterise optimum practice from welfare and ventilation perspectives.

(8) Long journeys of calves constitute a major concern. The main problems are:-

   a. Age at weaning – should the lower age limit for transport be increased

b. Are calves able to drink (do they drink) on vehicles equipped with unfamiliar nipple systems etc.?
c. Is the currently employed 9-1-9-24 travel time structure able to adequately protect calves in transit e.g. long journeys (including export for fattening)
d. Should a lower journey time maximum (e.g. 9 hours) be introduced for calves?
e. Should calves be provided with feed / water during the mid-journey break under the current legislation and if so how?
f. What are the long term health and welfare consequences for calves of current practice on long journeys
g. Should the practices for care, feeding and watering at control posts be more strictly prescribed for clave on long journeys

Most of these questions / issues should be addressed and better informed through research. There are no new research outputs identified in the systematic review that inform these practices

Issues relating to pigs

There are a number of specific issues relating to the transportation of pigs that were identified at the time of the implementation of EC 1/2005 and in subsequent review processed and which have remained unresolved since.

(7) The maximum stocking density for pigs is presented as a single figure (235 kg m^{-2}) on an area basis and primarily applies to pigs of around 100kg body weight. Clearly if this basis was used for smaller e.g. weaner pigs then the number of pigs per unit area would become problematic. Whilst common sense is currently employed it is suggested that research in the area might better inform future policy, advice and legislation as to the optimum stocking densities (space allowances) for pigs over a wide range of body weights.

(8) If pigs are to be fed and watered on-board trucks then space allowance should be adjusted accordingly.

(9) Head space is another issue that may require further research. The recommendation that there should be 15 cm above the highest part of a pig standing in a natural position has been the cause of much debate. It is claimed that this clearance is necessary to ensure adequate ventilation and thermal comfort for the pigs. It might suggested that further research is necessary to establish the optimum head space for pigs of different sizes in relation to animal movement and ventilation requirements (passive and mechanical ventilated vehicles?). Minimum deck heights have been the subject of recommendations in guidelines.

(10) It has been proposed that mechanical ventilation regimes and throughputs should be further investigated (beyond the research currently available) to ensure that ventilation will be adequate to ensure thermal comfort in large pigs on stationary vehicles under hot weather conditions.

(11) It has been recommended that pigs should not be fed less than 6 hours before transport either from the origin or from a control post on long journeys. It appears that this advice is based on limited published information concerning "motion sickness" in pigs. This topic should be addressed further and may require further research to confirm that this is appropriate practice.

(12) Research is available that suggests that factors affecting the welfare of pigs in transit include the type of farm system from which the animals came (e.g. outdoor organic or yards or indoor on slats) and abattoir standing time. The available research suggests that these factors may have more impact upon pig welfare than journey time per se. Clearly, in the case of system effects, this relates to pigs previous experience of handling, mixing and containment. Abattoir standing time will have wide ranging effects depending upon external conditions, where the vehicles are held relative to wind direction and sunlight (radiation). It is proposed that these issues may be pertinent also to other slaughter animal species and that further studies might be required to further elucidate the effects upon the animals and their responses.

Issues relating to sheep

A number of issues have been identified by the current and previous review processes that require consideration.

(5) It has been demonstrated the poor driving style puts sheep at risk of stress, postural instability and injury. It has been proposed that vehicle motion and driving style should be automatically monitored and recorded on sheep vehicles on long journeys by the fitting of accelerometry packages to vehicles. There appear to be no published trials on the validation of this proposal terms of the effect upon animal welfare or productivity.

(6) It is proposed also that space allowances for sheep should be reived to incorporate new allometric equations. This appears in the new Guides to Good Practice and further research is probably not required.

(7) An additional concern, however, is that inadequate floor space and head space for ventilation and thermal control on long journeys may increase the risk of heat stress. This area should receive further attention as there is little published information that might better inform new policy or advice.

(8) The provision of water on-board vehicles carrying sheep is not well studied also in terms of use, efficacy and outcomes in relation to drinker design and operation and environmental conditions, space allowance and journey time. This area might be better informed by new future research.

(9) It is suggested that dehydration is a risk in transported sheep as despite the resilience of this species in the face of water withdrawal under transport conditions in hot weather dehydration may occur relatively quickly. This topic would be addressed by the new research proposed above.

(10) The provision of water for sheep in markets has long been a contentious issue. The limited available research suggests that there may not be a requirement where journeys are not excessively long but the motivation to drink under a range of environmental and transport conditions has not been adequately addressed in previously published research. This topic might be better informed by new research initiatives.

Issues relating to poultry

Poultry represent a category of livestock in which there are some issues and areas on concern which were apparent at the implementation of EC 1/2005. Some of the legislative component of the Regulation had their origins in previous legislation and did not take full account of the scientific research available and reviewed in EFSA Opinions and other sources in the period 2002-2004. As a consequence subsequent reviews identified omissions and/or shortcomings in the Regulation. Many of these have yet to be addressed in term of both policy and further research. Some of the key issues are:-

(9) Under current Regulation EC 1/2005, unlike other species of livestock there is no definition of "long journeys". Thus, the feeding and watering intervals that impose the upper journey duration limit of 12 hours for poultry does not constitute a long journey and therefore does not require the use of higher standard vehicles. A consequence of this is that there are no specified temperature limits for poultry transport. Therefore, it is recommended that specific thermal limits should be defined for broilers, point of lay hens and end of lay hens. Specification of thermal comfort zones for the latter two groups will require further research. From previous research it is established that the upper temperature limit in a transport container for broilers should be 24-25 ºC, assuming a relative humidity of 70% or higher. The lower temperature limit for broilers in containers should be 5 ºC. Localised high air velocities should be avoided on passively ventilated vehicles by close attention to curtain construction and air inlet control. Measures should be taken to prevent wetting of broilers and laying hens prior to or during transport. It is suggested that for journeys of 4 hours or over, poultry vehicles should be equipped with mechanical ventilation systems with the capacity to modify both air temperature and humidity within prescribed limits (to be defined). It is proposed that policy should be developed to address these issues and that further research may be required to provide important fundamental evidence

(10) Another important issue wetting of poultry prior or during transport as in cold conditions the disruptive effect of water on bird insulation will greatly compromise thermoregulation resulting in potentially severe cold stress. Much of the underpinning science in this specific area is available but more research might be required to inform improved policy.

(11) The transport of newly hatched chicks may require also further examination. The available research suggests that journey time limits (based on yolk sac resource utilisation) are consistent with good chick welfare at this time. However, it might be proposed that new specific research addressing this assertion is merited.

(12) In keeping with the recommendations for broiler chickens new legislation might prescribe temperature limits for newly hatched chick transport. The proposed values are supported by existing research and further investigation may not be required.

(13) An area of improvement for newly hatched chick transport has been identified by the industry and merits / requires further investigation. Thus changes in chick box design to facilitate better ventilation and control of the thermal micro-environment might improve chick welfare and may require changes in the permissible stocking density / space allowance for chicks. This area should be studied as it offers a number of other potential benefits if proved appropriate.

(14) Inspection of poultry in respect of fitness to travel has long been a controversial issue and there are no new studies that better inform the issue. The development of an on-farm inspection guideline might facilitate progress but it is difficult to envisage the implementation strategy across the industry.

(15) Early feeding of newly hatched chicks has been recommended also to improve welfare during long transport to farms. It is not clear from published research if the optimum method for delivery and composition of feed and water prior to farm placement has been established

(16) Provision of water to poultry in transit (on different types of journey) has been proposed also and various systems have been considered. There is a

lack of published information that might inform decisions on these recommendations. Further investigation is merited.

(17) The head space / clearance for poultry in transport containers is still the subject of extensive debate. The benefits and disadvantages of more head space to allow standing and/or improved ventilation are the central matter so of concern. There is no new evidence available in the literature to inform this issue. Thus, perhaps new research is required to assess the problem and to identify the optimum box and vehicle design and practice.

(18) For broiler chicken and transport of end of lay hens it is recommended that the existence of metabolic diseases and other possible pathologies and injuries should be considered in all aspects of handling and journey planning. The research underpinning these concerns is mature and in place and no further investigation is required to help inform new strategies or policy in this area.

Issues relating to horses

There is continuing concern over many aspects of transport of horses particularly to slaughter. Pre-transport inspections are often inadequate and a code of practice and guidelines for this process are essential. Some attempt has been made to address this in the recently published DG SANCO Guides to Good Practice. Specific issues requiring further consideration include:-

(4) Should transport of horses (of mixed breed and “uncertain health status”) be limited to 12 hours? There appears to be no quality research that has addressed these issues.

(5) For sea transport should the time spent on a vessel on a ship be travel time or rest time? Again there is no sound evidence as to the impact on the animals of these procedures.

(6) The space allowances for horses should be presented as kg m^{-2} to account for size and breed differences in single consignments. The information required for implementation is available.

(7) It has been asserted that “there is a huge variation between breeds and within breeds in their thermoneutral zones” so it is difficult to define general limits. The effects of humidity have not been examined in any details in reliable publications. This area constitutes and obvious gap in knowledge and should be addressed through the appropriate research.
(8) The industry has identified benefits to diagonal placement / arrangement of horses on the vehicle and there is some published data to support this. Perhaps more comparative studies of transport stress in horses carried in different arrangements on the vehicle are merited to facilitate more sound recommendations?

Summary

The above summary has been prepared from the information presented in the three sources previously identified:-

(1) Stakeholder Feedback - Defra Animal Welfare Review of EU Regulations Workshop 17th November 2008 (published 20th February 2009)
(2) EFSA Opinion of 2011 (EFSA Journal 2011; 9(1):1996)
(3) Outputs of stakeholder and focus Guides to Good Practices for Animal Transport in the EU: (Consortium of the Animal Transport Guides Project (2017). ‘Good practices for animal transport in the EU: (SANCO/2015/G3/SI2.701422) - http://animaltransportguides.eu/)

Attempts have been made to identify the key issues that may still require resolution and as such constitute gaps in knowledge. Those issues have been included that have not been addressed adequately by the research publications identified in the systematic and narrative review processes. In addition it has been proposed that some of the gaps in knowledge that might be addressed through research and as such these might constitute future research priorities. Where appropriate this information may be represented in the overall summary and conclusions of the review and report.

References

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Methodology	Grant, M.J. and Booth, A. A.	Typology of reviews: an analysis of 14 review types and associated methodologies.	Health Info Libr J.	2009	26	2	91	108
Methodology	Khan, K. S., Kunz, R., Kleijnen, J. and Antes, G.	Systematic reviews to support evidence-based medicine: how to apply findings of healthcare research.	Royal Society of Medicine Press, London. Kunz, R., and A. D. Oxman.	2003				
Methodology	Uman, L	Systematic reviews and meta analyses	J Can Acad Child Adolesc Psychiatry	2011	20	1	57	59
Methodology	European Food Safety Authority	Guidance on the assessment criteria for applications for new or mdofied stunning methods regarding animal protection at the time of killing	European Food Safety Authority Journal	2018	16	7	5343	
Methodology	European Food Safety Authority	Application of systematic review methodology to food and feed safety assessments to support decision making	European Food Safety Authority Journal	2010	8	6	1637	
Systematic review	Adams-Progar, A. L.; Friend, T. H.; Holub, G. A.; Krenek, A. J.; Garey, S. M.; Terrill, C. L.	Effects of repeated transport on Holstein calf post-transport behavior and feed intake	JOURNAL OF ANIMAL SCIENCE	2015	93	2	731	736
Systematic review	Alam, M. R.; Gregory, N. G.; Jabbar, M. A.; Uddin, M. S.; Widdicombe, J. P.; Kibria, A. S. M. G.; Khan, M. S. I.; Mannan, A.	Frequency of dehydration and metabolic depletion in cattle and water buffalo transported from India to a livestock market in Bangladesh	ANIMAL WELFARE	2010	19	3	301	305
Systematic review	Ali, BH; Al-Qarawi, AA; Mousa, HM	Stress associated with road transportation in desert sheep and goats, and the effect of pretreatment with xylazine or sodium betaine	RESEARCH IN VETERINARY SCIENCE	2006	80	3	343	348

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Allano, Marion; Labrecque, Olivia; Batista, Edisleidy Rodriguez; Beauchamp, Guy; Bedard, Christian; Lavoie, Jean-Pierre; Leclere, Mathilde	Influence of short distance transportation on tracheal bacterial content and lower airway cytology in horses	VETERINARY JOURNAL	2016	214		47	49
Systematic review	Anderson, DE; Grubb, T; Silveira, F	The effect of short duration transportation on serum cortisol response in alpacas (Llama pacos)	VETERINARY JOURNAL	1999	157	2	189	191
Systematic review	Aoyama, Masato; Negishi, Akihito; Abe, Akiko; Maejima, Yuko; Sugita, Shoei	Short-term transportation in a small vehicle affects the physiological state and subsequent water consumption in goats	ANIMAL SCIENCE JOURNAL	2008	79	4	526	533
Systematic review	Apple, JK; Kegley, EB; Maxwell, CV; Rakes, LK; Galloway, D; Wistuba, TJ	Effects of dietary magnesium and short-duration transportation on stress response, postmortem muscle metabolism, and meat quality of finishing swine	JOURNAL OF ANIMAL SCIENCE	2005	83	7	1633	1645
Systematic review	Arthington, JD; Eicher, D; Kunkle, WE; Martin, FG	Effect of transportation and commingling on the acute-phase protein response, growth, and feed intake of newly weaned beef calves	JOURNAL OF ANIMAL SCIENCE	2003	81	5	1120	1125
Systematic review	Asala, Olayinka O.; Ayo, Joseph O.; Rekwot, Peter I.; Minka, Ndazo S.; Omoniwa, David O.; Adenkola, Adeshina Y.	Effect of ascorbic acid administration on erythrocyte osmotic fragility of pigs transported by road during the hot-dry season	VETERINARY RESEARCH COMMUNICATIONS	2011	35	4	245	254
Systematic review	Asala, Olayinka Oluwafemi; Ayo, Joseph Olusegun; Adenkola, Adeshina Yahaya; Minka, Ndazo Salka	Effects of road transportation on excitability scores of pigs administered with ascorbic acid during the hot-dry season	AFRICAN JOURNAL OF BIOTECHNOLOGY	2010	9	6	906	911
Systematic review	Averos, X.; Herranz, A.; Sanchez, R.; Comella, J. X.; Gosalvez, L. F.	Serum stress parameters in pigs transported to slaughter under commercial conditions in different seasons	VETERINARNI MEDICINA	2007	52	8	333	342
Systematic review	Averos, X.; Knowles, T. G.; Brown, S. N.; Warriss, P. D.; Gosalvez, L. F.	Factors affecting the mortality of pigs being transported to slaughter	VETERINARY RECORD	2008	163	13	386	390
Systematic review	Ayo, J. O.; Minka, N. S.; Sackey, A. K. B.; Adelaiye, A. B.	Responses of serum electrolytes of goats to twelve hours of road transportation during the hot-dry season in Nigeria, and the effect of pretreatment with ascorbic acid	ONDERSTEPOORT JOURNAL OF VETERINARY RESEARCH	2009	76	4	409	418
Systematic review	Ayo, JO; Minka, NS; Mamman, M	Excitability scores of goats administered ascorbic acid and transported during hot-dry conditions	JOURNAL OF VETERINARY SCIENCE	2006	7	2	127	131

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Becerril-Herrera, M.; Alonso-Spilsbury, M.; Trujillo Ortega, M. E.; Guerrero-Legarreta, I.; Ramirez-Necoechea, R.; Roldan-Santiago, P.; Perez-Sato, M.; Soni-Guillermo, E.; Mota-Rojas, D.	Changes in blood constituents of swine transported for 8 or 16 h to an Abattoir	MEAT SCIENCE	2010	86	4	945	948
Systematic review	Becerril-Herrera, Marcelino; Mota-Rojas, Daniel; Guerrero Legarreta, Isabel; Schunemann de Aluja, Aline; Lemus-Flores, Clemente; Gonzalez-Lozano, Miguel; Ramirez-Necoechea, Ramiro; Alonso-Spilsbury, Maria	Relevant aspects of swine welfare in transit	VETERINARIA MEXICO	2009	40	3	315	329
Systematic review	Bergoug, H.; Guinebretiere, M.; Tong, Q.; Roulston, N.; Romanini, C. E. B.; Exadaktylos, V.; Berckmans, D.; Garain, P.; Demmers, T. G. M.; McGonnell, I. M.; Bahr, C.; Burel, C.; Eterradossi, N.; Michel, V.	Effect of transportation duration of 1-day-old chicks on postplacement production performances and pododermatitis of broilers up to slaughter age	POULTRY SCIENCE	2013	92	12	3300	3309
Systematic review	Berry, N. L.; Johnson, A. K.; Hill, J.; Lonergan, S.; Karriker, L. A.; Stalder, K. J.	Loading gantry versus traditional chute for the finisher pig: Effect on welfare at the time of loading and performance measures and transport losses at the harvest facility	JOURNAL OF ANIMAL SCIENCE	2012	90	11	4028	4036
Systematic review	Berry, RJ; Lewis, NJ	The effect of duration and temperature of simulated transport on the performance of early-weaned piglets	CANADIAN JOURNAL OF ANIMAL SCIENCE	2001	81	2	199	204
Systematic review	Bertol, TM; Ellis, M; Ritter, MJ; McKeith, FK	Effect of feed withdrawal and handling intensity on longissimus muscle glycolytic potential and blood measurements in slaughter weight pigs	JOURNAL OF ANIMAL SCIENCE	2005	83	7	1536	1542
Systematic review	Bianchi, M; Petracci, M; Cavani, C	The influence of genotype, market live weight, transportation, and holding conditions prior to slaughter on broiler breast meat color	POULTRY SCIENCE	2006	85	1	123	128
Systematic review	BLACK, H; MATTHEWS, LR; BREMNER, KJ	THE BEHAVIOR OF MALE LAMBS TRANSPORTED BY SEA FROM NEW-ZEALAND TO SAUDI-ARABIA	NEW ZEALAND VETERINARY JOURNAL	1994	42	1	16	23
Systematic review	Bornett-Gauci, H. L. I.; Martin, J. E.; Arney, D. R.	The welfare of low-volume farm animals during transport and at slaughter: a review of current knowledge	ANIMAL WELFARE	2006	15	3	299	308

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
		and recommendations for future research						
Systematic review	Bradshaw, RH; Hall, SJG; Broom, DM	Behavioural and cortisol response of pigs and sheep during transport	VETERINARY RECORD	1996	138	10	233	234
Systematic review	Broom, DM	The effects of land transport on animal welfare	REVUE SCIENTIFIQUE ET TECHNIQUE-OFFICE INTERNATIONAL DES EPIZOOTIES	2005	24	2	683	691
Systematic review	Broom, DM	Transport stress in cattle and sheep with details of physiological, ethological and other indicators	DEUTSCHE TIERARZTLICHE WOCHENSCHRIFT	2003	110	3	83	+
Systematic review	Broom, DM; Goode, JA; Hall, SJG; Lloyd, DM; Parrott, RF	Hormonal and physiological effects of a 15 hour road journey in sheep: Comparison with the responses to loading, handling and penning in the absence of transport	BRITISH VETERINARY JOURNAL	1996	152	5	593	604
Systematic review	Brown, SN; Knowles, TG; Edwards, JE; Warriss, PD	Behavioural and physiological responses of pigs to being transported for up to 24 hours followed by six hours recovery in lairage	VETERINARY RECORD	1999	145	15	421	426
Systematic review	Brown, SN; Knowles, TG; Edwards, JE; Warriss, PD	Relationship between food deprivation before transport and aggression in pigs held in lairage before slaughter	VETERINARY RECORD	1999	145	22	630	634
Systematic review	Buil, T.; Maria, G. A.; Villarroel, M.; Liste, G.; Lopez, M.	CRITICAL POINTS IN THE TRANSPORT OF COMMERCIAL RABBITS TO SLAUGHTER IN SPAIN THAT COULD COMPROMISE ANIMALS' WELFARE	WORLD RABBIT SCIENCE	2004	12	4	269	279
Systematic review	Burlinguette, N. A.; Strawford, M. L.; Watts, J. M.; Classen, H. L.; Shand, P. J.; Crowe, T. G.	Broiler trailer thermal conditions during cold climate transport	CANADIAN JOURNAL OF ANIMAL SCIENCE	2012	92	2	109	122
Systematic review	Chandra, BS; Das, N	The handling and short-haul road transportation of spent buffaloes in relation to bruising and animal welfare	TROPICAL ANIMAL HEALTH AND PRODUCTION	2001	33	2	155	163

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Chauvin, C.; Hillion, S.; Balaine, L.; Michel, V.; Peraste, J.; Petetin, I.; Lupo, C.; Le Bouquin, S.	Factors associated with mortality of broilers during transport to slaughterhouse	ANIMAL	2011	5	2	287	293
Systematic review	Cheng, H. -W.; Jefferson, L.	Different Behavioral and physiological responses in two genetic lines of laying hens after transportation	POULTRY SCIENCE	2008	87	5	885	892
Systematic review	Chirase, NK; Greene, W; Purdy, CW; Loan, RW; Auvermann, BW; Parker, DB; Walborg, EF; Stevenson, DE; Xu, Y; Klaunig, JE	Effect of transport stress on respiratory disease, serum antioxidant status, and serum concentrations of lipid peroxidation biomarkers in beef cattle	AMERICAN JOURNAL OF VETERINARY RESEARCH	2004	65	6	860	864
Systematic review	Chulayo, A. Y.; Bradley, G.; Muchenje, V.	Effects of transport distance, lairage time and stunning efficiency on cortisol, glucose, HSPA1A and how they relate with meat quality in cattle	MEAT SCIENCE	2016	117		89	96
Systematic review	CLARK, DK; FRIEND, TH; DELLMEIER, G	THE EFFECT OF ORIENTATION DURING TRAILER TRANSPORT ON HEART-RATE, CORTISOL AND BALANCE IN HORSES	APPLIED ANIMAL BEHAVIOUR SCIENCE	1993	38	3-4	179	189
Systematic review	Cockram, MS; Baxter, EM; Smith, LA; Bell, S; Howard, CM; Prescott, RJ; Mitchell, MA	Effect of driver behaviour, driving events and road type on the stability and resting behaviour of sheep in transit	ANIMAL SCIENCE	2004	79		165	176
Systematic review	COCKRAM, MS; CORLEY, KTT	EFFECT OF PRE-SLAUGHTER HANDLING ON THE BEHAVIOR AND BLOOD COMPOSITION OF BEEF-CATTLE	BRITISH VETERINARY JOURNAL	1991	147	5	444	454
Systematic review	Cockram, MS; Kent, JE; Goddard, PJ; Waran, NK; Jackson, RE; McGilp, IM; Southall, EL; Amory, JR; McConnell, TI; O'Riordan, T; Wilkins, BS	Behavioural and physiological responses of sheep to 16 h transport and a novel environment post-transport	VETERINARY JOURNAL	2000	159	2	139	146
Systematic review	Cockram, MS; Kent, JE; Waran, NK; Muwanga, GM; Prytherch, S; Jackson, RE; Goddard, PJ	Effect of space allowance during transport on the physiological and behavioural responses of sheep	APPLIED ANIMAL BEHAVIOUR SCIENCE	1996	49	1	4	4
Systematic review	Conte, S.; Faucitano, L.; Bergeron, R.; Torrey, S.; Gonyou, H. W.; Crowe, T.; Tamminga, E. Toth; Widowski, T. M.	Effects of season, truck type, and location within truck on gastrointestinal tract temperature of market-weight pigs during transport	JOURNAL OF ANIMAL SCIENCE	2015	93	12	5840	5848
Systematic review	Cooke, R. F.; Guarnieri Filho, T. A.; Cappellozza, B. I.; Bohnert, D. W.	Rest stops during road transport: Impacts on performance and acute-phase protein responses of feeder cattle	JOURNAL OF ANIMAL SCIENCE	2013	91	11	5448	5454

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Correa Vieira, Frederico Marcio; Oliveira da Silva, Iran Jose; Delfino Barbosa Filho, Jose Antonio; Correa Vieira, Afranio Marcio	Productive losses on broiler preslaughter operations: effects of the distance from farms to abattoirs and of lairage time in a climatized holding area	REVISTA BRASILEIRA DE ZOOTECNIA-BRAZILIAN JOURNAL OF ANIMAL SCIENCE	2010	39	11	2471	2476
Systematic review	Correa Vieira, Frederico Marcio; Oliveira da Silva, Iran Jose; Delfino Barbosa Filho, Jose Antonio; Correa Vieira, Afranio Marcio; Rodrigues-Sarnighausen, Valeria Cristina; Garcia, Danilo de Brito	Thermal stress related with mortality rates on broilers' preslaughter operations: a lairage time effect study	CIENCIA RURAL	2011	41	9	1639	1644
Systematic review	Correa, J. A.; Gonyou, H. W.; Torrey, S.; Widowski, T.; Bergeron, R.; Crowe, T. G.; Laforest, J. P.; Faucitano, L.	Welfare and carcass and meat quality of pigs being transported for two hours using two vehicle types during two seasons of the year	CANADIAN JOURNAL OF ANIMAL SCIENCE	2013	93	1	43	55
Systematic review	Costa, LN; Lo Fiego, DP; Dall'Olio, S; Davoli, R; Russo, V	Influence of loading method and stocking density during transport on meat and dry-cured ham quality in pigs with different halothane genotypes	MEAT SCIENCE	1999	51	4	391	399
Systematic review	CREGIER, SE	ALLEVIATING ROAD TRANSIT STRESS ON HORSES	ANIMAL REGULATION STUDIES	1981	3	3	223	227
Systematic review	Cross, Nicola; van Doorn, Fraukje; Versnel, Caroline; Cawdell-Smith, Judy; Phillips, Clive	Effects of lighting conditions on the welfare of horses being loaded for transportation	JOURNAL OF VETERINARY BEHAVIOR-CLINICAL APPLICATIONS AND RESEARCH	2008	3	1	20	24
Systematic review	Cunningham, JJ; McSweeney, KP; Congleton, JJ	Development of a system for improved transportation and handling of full-sized pregnant sows at a metropolitan research facility	CONTEMPORARY TOPICS IN LABORATORY ANIMAL SCIENCE	1998	37	5	82	85
Systematic review	da Cunha Leme, Thays Mayra; Lencioni Titto, Evaldo Antonio; Titto, Cristiane Goncalves; Barbosa Amadeu, Claudia Caroline; Neto, Paulo Fantinato; Vilela, Reissa Alves; Franco Pereira, Alfredo Manuel	Influence of transportation methods and pre-slaughter rest periods on cortisol level in lambs	SMALL RUMINANT RESEARCH	2012	107	1	8	11
Systematic review	Dadgar, S.; Crowe, T. G.; Classen, H. L.; Watts, J. M.; Shand, P. J.	Broiler chicken thigh and breast muscle responses to cold stress during simulated transport before slaughter	POULTRY SCIENCE	2012	91	6	1454	1464

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Dadgar, S.; Lee, E. S.; Leer, T. L. V.; Burlinguette, N.; Classen, H. L.; Crowe, T. G.; Shand, P. J.	Effect of microclimate temperature during transportation of broiler chickens on quality of the pectoralis major muscle	POULTRY SCIENCE	2010	89	5	1033	1041
Systematic review	Dadgar, S.; Lee, E. S.; Leer, T. L. V.; Crowe, T. G.; Classen, H. L.; Shand, P. J.	Effect of acute cold exposure, age, sex, and lairage on broiler breast meat quality	POULTRY SCIENCE	2011	90	2	444	457
Systematic review	Dalla Costa, F. A.; Paranhos da Costa, M. J. R.; Faucitano, L.; Dalla Costa, O. A.; Lopes, L. S.; Renuncio, E.	Ease of handling, physiological response, skin lesions and meat quality in pigs transported in two truck types	ARCHIVOS DE MEDICINA VETERINARIA	2016	48	3	299	304
Systematic review	Dalmau, Antoni; Di Nardo, Antonio; Realini, Carolina Eva; Rodriguez, Pedro; Llonch, Pol; Temple, Deborah; Velarde, Antonio; Giansante, Daniele; Messori, Stefano; Villa, Paolo Dalla	Effect of the duration of road transport on the physiology and meat quality of lambs	ANIMAL PRODUCTION SCIENCE	2014	54	2	179	186
Systematic review	Das, KS; Srivastava, BB; Das, N	Standing orientation and behaviour of goats during short-haul road transportation	SMALL RUMINANT RESEARCH	2001	41	1	91	94
Systematic review	De la Fuente, J.; Sanchez, M.; Perez, C.; Lauzurica, S.; Vieira, C.; Gonzalez de Chavarri, E.; Diaz, M. T.	Physiological response and carcass and meat quality of suckling lambs in relation to transport time and stocking density during transport by road	ANIMAL	2010	4	2	250	258
Systematic review	de la Fuente, Jesus; Gonzalez de Chavarri, Elisabeth; Sanchez, Monica; Vieira, Ceferina; Lauzurica, Sara; Teresa Diaz, Maria; Perez, Concepcion	The effects of journey duration and space allowance on the behavioural and biochemical measurements of stress responses in suckling lambs during transport to an abattoir	APPLIED ANIMAL BEHAVIOUR SCIENCE	2012	142	1-2	30	41
Systematic review	Delezie, E.; Swennen, Q.; Buyse, J.; Decuypere, E.	The effect of feed withdrawal and crating density in transit on metabolism and meat quality of broilers at slaughter weight	POULTRY SCIENCE	2007	86	7	1414	1423
Systematic review	Delfino Barbosa Filho, Jose Antonio; Correa Vieira, Frederico Marcio; Oliveira da Silva, Iran Jose; Garcia, Danilo de Brito; Neves da Silva, Marco Aurelio; Fernandes Fonseca, Bruno Henrique	Poultry transport: microclimate characterization of the truck during the winter	REVISTA BRASILEIRA DE ZOOTECNIA-BRAZILIAN JOURNAL OF ANIMAL SCIENCE	2009	38	12	2442	2446

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Di Martino, Guido; Capello, Katia; Stefani, Anna Lisa; Tripepi, Luca; Garbo, Angelica; Speri, Marina; Trolese, Matteo; Brichese, Michele; Marangon, Stefano; Bonfanti, Lebana	The effect of crate height on the behavior of female turkeys during commercial pre-slaughter transportation	ANIMAL SCIENCE JOURNAL	2017	88	10	1651	1657
Systematic review	Diaz, M. T.; Vieira, C.; Perez, C.; Lauzurica, S.; Gonzalez de Chavarri, E.; Sanchez, M.; De la Fuente, J.	Effect of lairage time (0 h, 3 h, 6 h or 12 h) on glycogen content and meat quality parameters in suckling lambs	MEAT SCIENCE	2014	96	2	653	660
Systematic review	Doktor, Joanna; Poltowicz, Katarzyna	EFFECT OF TRANSPORT TO THE SLAUGHTERHOUSE ON STRESS INDICATORS AND MEAT QUALITY OF BROILER CHICKENS	ANNALS OF ANIMAL SCIENCE	2009	9	3	307	317
Systematic review	Donofre, Ana C.; da Silva, Iran J. O.; Nazareno, Aerica C.	Mechanical vibrations: A stressor in the transport of chicken	REVISTA BRASILEIRA DE ENGENHARIA AGRICOLA E AMBIENTAL	2014	18	4	454	458
Systematic review	Donofre, Ana Carolina; Oliveira da Silva, Iran Jose; Nazareno, Aerica Cirqueira; de Paula Ferreira, Iuri Emmanuel	Mechanical vibrations in the transport of hatching eggs and the losses caused in the hatch and quality of broiler chicks	JOURNAL OF AGRICULTURAL ENGINEERING	2017	48	1	36	41
Systematic review	dos Santos, V. M.; Dallago, B. S. L.; Racanicci, A. M. C.; Santana, A. P.; Bernal, F. E. M.	Effects of season and distance during transport on broiler chicken meat	POULTRY SCIENCE	2017	96	12	4270	4279
Systematic review	Downing, J. A.; Kerr, M. J.; Hopkins, D. L.	The effects of pre-transport supplementation with electrolytes and betaine on performance, carcass yield and meat quality of broilers in summer and winter	LIVESTOCK SCIENCE	2017	205		16	23
Systematic review	Drain, Mairead E.; Whiting, Terry L.; Rasali, Drona P.; D'Angiolo, Vic A.	Warm weather transport of broiler chickens in Manitoba. I. Farm management factors associated with death loss in transit to slaughter	CANADIAN VETERINARY JOURNAL-REVUE VETERINAIRE CANADIENNE	2007	48	1	76	80
Systematic review	Driessen, B.; Peeters, E.; Geers, R.	Influence of olfactory substances on the heart rate and lying behaviour of pigs during transport simulation	ANIMAL WELFARE	2008	17	2	155	160
Systematic review	Duvaux-Ponter, C; Roussel, S; Tessier, J; Sauvant, D; Ficheux, C; Boissy, A	Physiological effects of repeated transport in pregnant goats and their offspring	ANIMAL RESEARCH	2003	52	6	553	566

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Earley, B.	The effect of transport by road and sea on physiology, immunity, and behavior of beef cattle.	JOURNAL OF ANIMAL SCIENCE	2006	84		272	272
Systematic review	Earley, B.; Fisher, A. D.; O'Riordan, E. G.	Effects of pre-transport fasting on the physiological responses of young cattle to 8-hour road transport	IRISH JOURNAL OF AGRICULTURAL AND FOOD RESEARCH	2006	45	1	51	60
Systematic review	Ekiz, Bulent; Ekiz, Elif Ergul; Kocak, Omur; Yalcintan, Hulya; Yilmaz, Alper	Effect of pre-slaughter management regarding transportation and time in lairage on certain stress parameters, carcass and meat quality characteristics in Kivircik lambs	MEAT SCIENCE	2012	90	4	967	976
Systematic review	Erisir, Z.; Poyraz, Oe.; Erisir, M.; Onbasilar, E. E.; Erdem, E.	The Changes of the Body Weight and Some Blood Parameters of Pekin Ducklings Dependent on Transportation Duration	Journal of Animal and Veterinary Advances	2008	7	10	1190	1195
Systematic review	Faucitano, L.	Invited Review: Effects of lairage and slaughter conditions on animal welfare and pork quality	CANADIAN JOURNAL OF ANIMAL SCIENCE	2010	90	4	461	469
Systematic review	Fazio, E.; Medica, P.; Cravana, C.; Cavaleri, S.; Ferlazzo, A.	Effect of temperament and prolonged transportation on endocrine and functional variables in young beef bulls	VETERINARY RECORD	2012	171	25	644	+
Systematic review	Fazio, E.; Medica, P.; Cravana, C.; Giacoppo, E.; Ferlazzo, A.	Physiological variables of horses after road transport	ANIMAL	2009	3	9	1313	1318
Systematic review	Fazio, Esterina; Medica, Pietro; Cravana, Cristina; Aveni, Francesca; Ferlazzo, Adriana	Comparative endocrinological responses to short transportation of Equidae (Equus asinus and Equus caballus)	ANIMAL SCIENCE JOURNAL	2013	84	3	258	263
Systematic review	Fernandez, X.; Bouillier-Oudot, M.; Molette, C.; Bernadet, M. D.; Manse, H.	Duration of transport and holding in lairage at constant postprandial delay to slaughter-Effects on fatty liver and breast muscle quality in mule ducks	POULTRY SCIENCE	2011	90	10	2360	2369
Systematic review	Fike, Karol; Spire, Mark F.	Transportation of cattle	VETERINARY CLINICS OF NORTH AMERICA-FOOD ANIMAL PRACTICE	2006	22	2	305	+
Systematic review	Fitzgerald, R. F.; Stalder, K. J.; Matthews, J. O.; Kaster, C. M. Schultz; Johnson, A. K.	Factors associated with fatigued, injured, and dead pig frequency during transport and lairage at a commercial abattoir	JOURNAL OF ANIMAL SCIENCE	2009	87	3	1156	1166

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Foster, Susan F.; Overall, Karen L.	The welfare of Australian livestock transported by sea	VETERINARY JOURNAL	2014	200	2	205	209
Systematic review	Fox, J.; Widowski, T.; Torrey, S.; Nannoni, E.; Bergeron, R.; Gonyou, H. W.; Brown, J. A.; Crowe, T.; Mainau, E.; Faucitano, L.	Water sprinkling market pigs in a stationary trailer. 1. Effects on pig behaviour, gastrointestinal tract temperature and trailer micro-climate	LIVESTOCK SCIENCE	2014	160		113	123
Systematic review	Fraqueza, MJ; Roseiro, LC; Almeida, J; Matias, E; Santos, C; Randall, JM	Effects of lairage temperature and holding time on pig behaviour and on carcass and meat quality	APPLIED ANIMAL BEHAVIOUR SCIENCE	1998	60	4	317	330
Systematic review	FREEMAN, BM; KETTLEWELL, PJ; MANNING, ACC; BERRY, PS	STRESS OF TRANSPORTATION FOR BROILERS	VETERINARY RECORD	1984	114	12	286	287
Systematic review	Friend, TH	Dehydration, stress, and water consumption of horses during long-distance commercial transport	JOURNAL OF ANIMAL SCIENCE	2000	78	10	2568	2580
Systematic review	Fukasawa, Michiru	The calf training for loading onto vehicle at weaning	ANIMAL SCIENCE JOURNAL	2012	83	11	759	766
Systematic review	Gade, P. Barton	Effect of rearing system and mixing at loading on transport and lairage behaviour and meat quality: comparison of outdoor and conventionally raised pigs	ANIMAL	2008	2	6	902	911
Systematic review	Gade, P. Barton	Effect of rearing system and mixing at loading on transport and lairage behaviour and meat quality: comparison of free range and conventionally raised pigs	ANIMAL	2008	2	8	1238	1246
Systematic review	Gade, P. Barton; Christensen, L.; Baltzer, M.; Petersen, J. Valentin	Causes of pre-slaughter mortality in emphasis on Danish slaughter pigs with special transport	ANIMAL WELFARE	2007	16	4	459	470
Systematic review	Gade, PB; Christensen, L	Effect of different stocking densities during transport on welfare and meat quality in Danish slaughter pigs	MEAT SCIENCE	1998	48	3-4	237	247
Systematic review	Garcia, Arlene; Pirner, Glenna; Picinin, Guilherme; May, Matthew; Guay, Kimberly; Backus, Brittany; Sutherland, Mhairi; McGlone, John	Effect of Provision of Feed and Water during Transport on the Welfare of Weaned Pigs	ANIMALS	2015	5	2	407	425

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Garcia, Arlene; Sutherland, Mhairi; Pirner, Glenna; Picinin, Guilherme; May, Matthew; Backus, Brittany; McGlone, John	Impact of Providing Feed and/or Water on Performance, Physiology, and Behavior of Weaned Pigs during a 32-h Transport	ANIMALS	2016	6	5		
Systematic review	Garcia-Celdran, Marta; Ramis, Guillermo; Jose Quereda, Juan; Armero, Eva	Reduction of transport-induced stress on finishing pigs by increasing lairage time at the slaughter house	JOURNAL OF SWINE HEALTH AND PRODUCTION	2012	20	3	118	122
Systematic review	Gebresenbet, Girma; Aradom, Samuel; Bulitta, Fufa S.; Hjerpe, Eva	Vibration levels and frequencies on vehicle and animals during transport	BIOSYSTEMS ENGINEERING	2011	110	1	10	19
Systematic review	Gerritzen, M. A.; Hindle, V. A.; Steinkamp, K.; Reimert, H. G. M.; van der Werf, J. T. N.; Marahrens, M.	The effect of reduced loading density on pig welfare during long distance transport	ANIMAL	2013	7	11	1849	1857
Systematic review	Geverink, NA; Buhnemann, A; Van de Burgwal, JA; Lambooij, E; Blokhuis, HJ; Wiegant, VM	Responses of slaughter pigs to transport and lairage sounds	PHYSIOLOGY & BEHAVIOR	1998	63	4	667	673
Systematic review	Geverink, NA; Kappers, A; van de Burgwal, JA; Lambooij, E; Blokhuis, HJ; Wiegant, VM	Effects of regular moving and handling on the behavioral and physiological responses of pigs to preslaughter treatment and consequences for subsequent meat quality	JOURNAL OF ANIMAL SCIENCE	1998	76	8	2080	2085
Systematic review	Goldhawk, C.; Crowe, T.; Janzen, E.; Gonzalez, L. A.; Kastelic, J.; Pajor, E.; Schwartzkopf-Genswein, K. S.	Trailer microclimate during commercial transportation of feeder cattle and relationship to indicators of cattle welfare	JOURNAL OF ANIMAL SCIENCE	2014	92	11	5155	5165
Systematic review	Goldhawk, C.; Janzen, E.; Gonzalez, L. A.; Crowe, T.; Kastelic, J.; Kehler, C.; Siemens, M.; Ominski, K.; Pajor, E.; Schwartzkopf-Genswein, K. S.	Trailer temperature and humidity during winter transport of cattle in Canada and evaluation of indicators used to assess the welfare of cull beef cows before and after transport	JOURNAL OF ANIMAL SCIENCE	2015	93	7	3639	3653
Systematic review	Goldhawk, C.; Janzen, E.; Gonzalez, L. A.; Crowe, T.; Kastelic, J.; Pajor, E.; Schwartzkopf-Genswein, K. S.	Trailer microclimate and calf welfare during fall-run transportation of beef calves in Alberta	JOURNAL OF ANIMAL SCIENCE	2014	92	11	5142	5154
Systematic review	Gonzalez, L. A.; Schwartzkopf-Genswein, K. S.; Bryan, M.; Silasi, R.; Brown, F.	Relationships between transport conditions and welfare outcomes during commercial long haul transport of cattle in North America	JOURNAL OF ANIMAL SCIENCE	2012	90	10	3640	3651
Systematic review	Gonzalez, L. A.; Schwartzkopf-Genswein, K. S.; Bryan, M.; Silasi, R.; Brown, F.	Factors affecting body weight loss during commercial long haul transport of cattle in North America	JOURNAL OF ANIMAL SCIENCE	2012	90	10	3630	3639

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Gonzalez, L. A.; Schwartzkopf-Genswein, K. S.; Bryan, M.; Silasi, R.; Brown, F.	Space allowance during commercial long distance transport of cattle in North America	JOURNAL OF ANIMAL SCIENCE	2012	90	10	3618	3629
Systematic review	Goumon, S.; Bergeron, R.; Faucitano, L.; Crowe, T.; Connor, M. L.; Gonyou, H. W.	Effect of previous ramp exposure and regular handling on heart rate, ease of handling and behaviour of near market-weight pigs during a simulated loading	CANADIAN JOURNAL OF ANIMAL SCIENCE	2013	93	4	461	470
Systematic review	Goumon, S.; Brown, J. A.; Faucitano, L.; Bergeron, R.; Widowski, T. M.; Crowe, T.; Connor, M. L.; Gonyou, H. W.	Effects of transport duration on maintenance behavior, heart rate and gastrointestinal tract temperature of market-weight pigs in 2 seasons	JOURNAL OF ANIMAL SCIENCE	2013	91	10	4925	4935
Systematic review	Goumon, S.; Faucitano, L.; Bergeron, R.; Crowe, T.; Connor, M. L.; Gonyou, H. W.	Effect of ramp configuration on easiness of handling, heart rate, and behavior of near-market weight pigs at unloading	JOURNAL OF ANIMAL SCIENCE	2013	91	8	3889	3898
Systematic review	Goumon, Sebastien; Faucitano, Luigi	Influence of loading handling and facilities on the subsequent response to pre-slaughter stress in pigs	LIVESTOCK SCIENCE	2017	200		6	13
Systematic review	Grandin, Temple	Transport Fitness of Cull Sows and Boars: A Comparison of Different Guidelines on Fitness for Transport	ANIMALS	2016	6	12		
Systematic review	Grandin, Temple; Shivley, Chelsey	How Farm Animals React and Perceive Stressful Situations Such As Handling, Restraint, and Transport	ANIMALS	2015	5	4	1233	1251
Systematic review	Gregory, N. G.; Benson, T.; Smith, N.; Mason, C. W.	Sheep handling and welfare standards in livestock markets in the UK	JOURNAL OF AGRICULTURAL SCIENCE	2009	147		333	344
Systematic review	Guise, HJ; Riches, HL; Hunter, EJ; Jones, TA; Warriss, PD; Kettlewell, PJ	The effect of stocking density in transit on the carcass quality and welfare of slaughter pigs: 1. Carcass measurements	MEAT SCIENCE	1998	50	4	439	446
Systematic review	Hagenmaier, J. A.; Reinhardt, C. D.; Bartle, S. J.; Henningson, J. N.; Ritter, M. J.; Calvo-Lorenzo, M. S.; Vogel, G. J.; Guthrie, C. A.; Siemens, M. G.; Thomson, D. U.	Effect of handling intensity at the time of transport for slaughter on physiological response and carcass characteristics in beef cattle fed ractopamine hydrochloride	JOURNAL OF ANIMAL SCIENCE	2017	95	5	1963	1976
Systematic review	Hall, SJG; Kirkpatrick, SM; Lloyd, DM; Broom, DM	Noise and vehicular motion as potential stressors during the transport of sheep	ANIMAL SCIENCE	1998	67		467	473

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Harmon, J. D.; Hoff, S. J.; Baas, T. J.; Zhao, Y.; Xin, H.; Follett, L. R.	EVALUATION OF CONDITIONS DURING WEANED PIG TRANSPORT	APPLIED ENGINEERING IN AGRICULTURE	2017	33	6	901	912
Systematic review	Harris, T	Animal transport and welfare: a global challenge	REVUE SCIENTIFIQUE ET TECHNIQUE-OFFICE INTERNATIONAL DES EPIZOOTIES	2005	24	2	647	653
Systematic review	Hartung, J; Marahrens, M; von Holleben, K	Recommendations for future development in cattle transport in Europe	DEUTSCHE TIERARZTLICHE WOCHENSCHRIFT	2003	110	3	128	130
Systematic review	Hazard, D.; Fernandez, X.; Pinguet, J.; Chambon, C.; Letisse, F.; Portais, J.-C.; Wadih-Moussa, Z.; Remignon, H.; Molette, C.	Functional genomics of the muscle response to restraint and transport in chickens	JOURNAL OF ANIMAL SCIENCE	2011	89	9	2717	2730
Systematic review	Henrikson, Z. A.; Vermette, C. J.; Schwean-Lardner, K.; Crowe, T. G.	Effects of cold exposure on physiology, meat quality, and behavior of turkey hens and toms crated at transport density	POULTRY SCIENCE	2018	97	2	347	357
Systematic review	Herskin, Mette S.; Fogsgaard, Katrine K.; Erichsen, Ditte; Bonnichsen, Mia; Gaillard, Charlotte; Thodberg, Karen	Housing of Cull Sows in the Hours before Transport to the Abattoir-An Initial Description of Sow Behaviour While Waiting in a Transfer Vehicle	ANIMALS	2017	7	1		
Systematic review	Hoffman, L. C.; Fisher, P.	Comparison of the effects of different transport conditions and lairage times in a Mediterranean climate in South Africa on the meat quality of commercially crossbred Large white x Landrace pigs	JOURNAL OF THE SOUTH AFRICAN VETERINARY ASSOCIATION-TYDSKRIF VAN DIE SUID-AFRIKAANSE VETERINERE VERENIGING	2010	81	4	224	227
Systematic review	Hogan, James P.; Petherick, J. Carol; Phillips, Clive J. C.	The physiological and metabolic impacts on sheep and cattle of feed and water deprivation before and during transport	NUTRITION RESEARCH REVIEWS	2007	20	1	17	28
Systematic review	Huertas, S. M.; Gil, A. D.; Piaggio, J. M.; van Eerdenburg, F. J. C. M.	Transportation of beef cattle to slaughterhouses and how this relates to animal welfare and carcase bruising in an extensive production system	ANIMAL WELFARE	2010	19	3	281	285

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Iacono, C. M.; Friend, T. H.; Johnson, R. D.; Krawczel, P. D.; Archer, G. S.	A preliminary study on the utilization of an onboard watering system by horses during commercial transport	APPLIED ANIMAL BEHAVIOUR SCIENCE	2007	105	1-3	227	231
Systematic review	Iacono, Christa; Friend, Ted; Keen, Heidi; Martin, Tracy; Krawczel, Peter	Effects of density and water availability on the behavior, physiology, and weight loss of slaughter horses during transport	JOURNAL OF EQUINE VETERINARY SCIENCE	2007	27	8	355	361
Systematic review	Ingram, JR; Cook, CJ; Harris, PJ	The effect of transport on core and peripheral body temperatures and heart rate of sheep	ANIMAL WELFARE	2002	11	1	103	112
Systematic review	Jackson, RE; Cockram, MS; Goddard, PJ; Doherty, OM; McGilp, IM; Waran, NK	The effects of 24H water deprivation when associated with some aspects of transportation on the behaviour and blood chemistry of sheep	ANIMAL WELFARE	1999	8	3	229	241
Systematic review	Jacobs, Leonie; Delezie, Evelyne; Duchateau, Luc; Goethals, Klara; Ampe, Bart; Buyse, Johan; Tuyttens, Frank Andre Maurice	Impact of transportation duration on stress responses in day-old chicks from young and old breeders	RESEARCH IN VETERINARY SCIENCE	2017	112		172	176
Systematic review	Jacobs, Leonie; Delezie, Evelyne; Duchateau, Luc; Goethals, Klara; Ampe, Bart; Lambrecht, Evelien; Gellynck, Xavier; Tuyttens, Frank A. M.	Effect of post-hatch transportation duration and parental age on broiler chicken quality, welfare, and productivity	POULTRY SCIENCE	2016	95	9	1973	1979
Systematic review	Jacobson, LH; Cook, CJ	Partitioning psychological and physical sources of transport-related stress in young cattle	VETERINARY JOURNAL	1998	155	2	205	208
Systematic review	Janczak, AM; Pedersen, LJ; Bakken, M	Effects of variation in pre-test transport duration and animal age on behaviour in the porcine elevated plus-maze - a brief report	APPLIED ANIMAL BEHAVIOUR SCIENCE	2002	77	3	233	238
Systematic review	Jarvis, AM; Cockram, MS; McGilp, IM	Bruising and biochemical measures of stress, dehydration and injury determined at slaughter in sheep transported from farms or markets	BRITISH VETERINARY JOURNAL	1996	152	6	719	722
Systematic review	Jones, Tracey A.; Waitt, Corri; Dawkins, Marian S.	Sheep lose balance, slip and fall less when loosely packed in transit where they stand close to but not touching their neighbours	APPLIED ANIMAL BEHAVIOUR SCIENCE	2010	123	1-2	16	23
Systematic review	Kadim, I. T.; Mahgoub, O.; Alkindi, A. Y.; Al-Marzooqi, W.; Al-Saqri, N. M.; Almaney, M.; Mahmoud, I. Y.	Effect of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics in two age groups of Omani sheep	ASIAN-AUSTRALASIAN JOURNAL OF ANIMAL SCIENCES	2007	20	3	424	431

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Kadim, Isam T.; Mahgoub, Osman; Al-Marzooqi, Waleed; Khalaf, Samera; Al-Sinawi, Shadia S. H.; Al-Amri, Issa	Effects of transportation during the hot season, breed and electrical stimulation on histochemical and meat quality characteristics of goat longissimus muscle	ANIMAL SCIENCE JOURNAL	2010	81	3	352	361
Systematic review	Kadim, IT; Mahgoub, O; Al-Kindi, A; Al-Marzooqi, W; Al-Saqri, NM	Effects of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics of three breeds of Omani goats	MEAT SCIENCE	2006	73	4	626	634
Systematic review	Kannan, G; Heath, JL; Wabeck, CJ; Souza, MCP; Howe, JC; Mench, JA	Effects of crating and transport on stress and meat quality characteristics in broilers	POULTRY SCIENCE	1997	76	3	523	529
Systematic review	Kannan, G; Mench, JA	Prior handling does not significantly reduce the stress response to pre-slaughter handling in broiler chickens	APPLIED ANIMAL BEHAVIOUR SCIENCE	1997	51	1-2	87	99
Systematic review	Karaman, Mesut	Effect of Transport Time on Body Performance of Broilers During Transit to Slaughter House	JOURNAL OF ANIMAL AND VETERINARY ADVANCES	2009	8	8	1555	1557
Systematic review	Kephart, K. B.; Harper, M. T.; Raines, C. R.	Observations of market pigs following transport to a packing plant	JOURNAL OF ANIMAL SCIENCE	2010	88	6	2199	2203
Systematic review	Kettlewell, PJ; Hoxey, RP; Hampson, CJ; Green, NR; Veale, BM; Mitchell, MA	Design and operation of a prototype mechanical ventilation system for livestock transport vehicles	JOURNAL OF AGRICULTURAL ENGINEERING RESEARCH	2001	79	4	429	439
Systematic review	Kettlewell, PJ; Hoxey, RP; Mitchell, MA	Heat produced by broiler chickens in a commercial transport vehicle	JOURNAL OF AGRICULTURAL ENGINEERING RESEARCH	2000	75	3	315	326
Systematic review	Khosravinia, Heshmatollah	Physiological responses of newly hatched broiler chicks to increasing journey distance during road transportation	ITALIAN JOURNAL OF ANIMAL SCIENCE	2015	14	3	519	523
Systematic review	Kim, DH; Woo, JH; Lee, CY	Effects of stocking density and transportation time of market pigs on their behaviour, plasma concentrations of glucose and stress-associated enzymes and carcass quality	ASIAN-AUSTRALASIAN JOURNAL OF ANIMAL SCIENCES	2004	17	1	116	121

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Kittelsen, K. E.; Granquist, E. G.; Vasdal, G.; Tolo, E.; Moe, R. O.	Effects of catching and transportation versus pre-slaughter handling at the abattoir on the prevalence of wing fractures in broilers	ANIMAL WELFARE	2015	24	4	387	389
Systematic review	Knezacek, T. D.; Olkowski, A. A.; Kettlewell, P. J.; Mitchell, M. A.; Classen, H. L.	Temperature gradients in trailers and changes in broiler rectal and core body temperature during winter transportation in Saskatchewan	CANADIAN JOURNAL OF ANIMAL SCIENCE	2010	90	3	321	330
Systematic review	Knowles, TG; Brown, SN; Edwards, JE; Warriss, PD	Ambient temperature below which pigs should not be continuously showered in lairage	VETERINARY RECORD	1998	143	21	575	578
Systematic review	Knowles, TG; Warriss, PD; Brown, SN; Edwards, JE	Effects on cattle of transportation by road for up to 31 hours	VETERINARY RECORD	1999	145	20	575	582
Systematic review	Knowles, TG; Warriss, PD; Brown, SN; Kestin, SC; Edwards, JE; Perry, AM; Watkins, PE; Phillips, AJ	Effects of feeding, watering and resting intervals on lambs transported by road and ferry to France	VETERINARY RECORD	1996	139	14	335	339
Systematic review	Knowles, TG; Wilkins, LJ	The problem of broken bones during the handling of laying hens - A review	POULTRY SCIENCE	1998	77	12	1798	1802
Systematic review	Kojima, C. J.; Kattesh, H. G.; Roberts, M. P.; Sun, T.	Physiological and immunological responses to weaning and transport in the young pig: Modulation by administration of porcine somatotropin	JOURNAL OF ANIMAL SCIENCE	2008	86	11	2913	2919
Systematic review	Laaksonen, Sauli; Jokelainen, Pikka; Pusenius, Jyrki; Oksanen, Antti	Is transport distance correlated with animal welfare and carcass quality of reindeer (Rangifer tarandus tarandus)?	ACTA VETERINARIA SCANDINAVICA	2017	59			
Systematic review	Lambooij, E.; van der Werf, J. T. N.; Reimert, H. G. M.; Hindle, V. A.	Compartment height in cattle transport vehicles	LIVESTOCK SCIENCE	2012	148	1-2	87	94
Systematic review	LAMBOOY, E; ENGEL, B	TRANSPORT OF SLAUGHTER PIGS BY TRUCK OVER A LONG-DISTANCE - SOME ASPECTS OF LOADING DENSITY AND VENTILATION	LIVESTOCK PRODUCTION SCIENCE	1991	28	2	163	174
Systematic review	LEADON, D; FRANK, C; BACKHOUSE, W	A PRELIMINARY-REPORT ON STUDIES ON EQUINE TRANSIT STRESS	JOURNAL OF EQUINE VETERINARY SCIENCE	1989	9	4	200	202

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Lewis, C. R. G.; Krebs, N.; Hulbert, L. E.; McGlone, J. J.	Use of a putative maternal pheromone during transport and the effect of trailer temperatures on pig losses and welfare	ANIMAL PRODUCTION SCIENCE	2010	50	10	916	924
Systematic review	Lewis, Nora J.	Transport of early weaned piglets	APPLIED ANIMAL BEHAVIOUR SCIENCE	2008	110	1-2	128	135
Systematic review	Lewis, Nora J.; Berry, Robert J.	Effects of season on the behaviour of early-weaned piglets during and immediately following transport	APPLIED ANIMAL BEHAVIOUR SCIENCE	2006	100	3-4	182	192
Systematic review	Li, Zhao-Yang; Lin, Jia; Sun, Feng; Li, Hui; Xia, Jun; Li, Xue-Nan; Ge, Jing; Zhang, Cong; Li, Jin-Long	Transport stress induces weight loss and heart injury in chicks: disruption of ionic homeostasis via modulating ion transporting ATPases	ONCOTARGET	2017	8	15	24142	24153
Systematic review	Llonch, P.; King, E. M.; Clarke, K. A.; Downes, J. M.; Green, L. E.	A systematic review of animal based indicators of sheep welfare on farm, at market and during transport, and qualitative appraisal of their validity and feasibility for use in UK abattoirs	VETERINARY JOURNAL	2015	206	3	289	297
Systematic review	Machovcova, Zuzana; Vecerek, Vladimir; Voslarova, Eva; Malena, Milan; Conte, Francesca; Bedanova, Iveta; Vecerkova, Lenka	Pre-slaughter mortality among turkeys related to their transport	ANIMAL SCIENCE JOURNAL	2017	88	4	705	711
Systematic review	Magnani, Diego; Cafazzo, Simona; Cala, Pietro; Razzuoli, Elisabetta; Amadori, Massimo; Bernardini, Daniele; Gerardi, Gabriele; Costa, Leonardo Nanni	Effect of long transport and environmental conditions on behaviour and blood parameters of postweaned piglets with different reactivity to backtest	LIVESTOCK SCIENCE	2014	162		201	208
Systematic review	Malena, M.; Voslarova, E.; Tomanova, P.; Lepkova, R.; Bedanova, I.; Vecerek, V.	Influence of travel distance and the season upon transport-induced mortality in fattened cattle	ACTA VETERINARIA BRNO	2006	75	4	619	624
Systematic review	Malena, M.; Voslarova, Eva; Kozak, A.; Belobradek, P.; Bedanova, I.; Steinhauser, L.; Vecerek, V.	Comparison of mortality rates in different categories of pigs and cattle during transport for slaughter	ACTA VETERINARIA BRNO	2007	76		S109	S116
Systematic review	Marencic, Dejan; Ivankovic, Ante; Pintic, Vinko; Kelava, Nikolina; Jakopovic, Tomislav	Effect of the transport duration time and season on some physicochemical properties of beef meat	ARCHIV FUR TIERZUCHT-ARCHIVES OF ANIMAL BREEDING	2012	55	2	123	131
Systematic review	Maria, GA; Villarroel, M; Sanudo, C; Olleta, JL; Gebresenbet, G	Effect of transport time and ageing on aspects of beef quality	MEAT SCIENCE	2003	65	4	1335	1340

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Marlin, D.; Kettlewell, P.; Parkin, T.; Kennedy, M.; Broom, D.; Wood, J.	Welfare and health of horses transported for slaughter within the European Union Part 1: Methodology and descriptive data	EQUINE VETERINARY JOURNAL	2011	43	1	78	87
Systematic review	Marques, R. S.; Cooke, R. F.; Francisco, C. L.; Bohnert, D. W.	Effects of twenty-four hour transport or twenty-four hour feed and water deprivation on physiologic and performance responses of feeder cattle	JOURNAL OF ANIMAL SCIENCE	2012	90	13	5040	5046
Systematic review	Martinez-Rodriguez, R.; Roldan-Santiago, P.; Orozco-Gregorio, H.; Trujillo-Ortega, M.; Mora-Medina, P.; Gonzalez-Lozano, M.; Sanchez-Hernandez, M.; Bonilla-Jaime, H.; Garcia-Herrera, R.; Hernandez-Trujillo, E.; Mota-Rojas, D.	Physiological responses and blood gas exchange following long-distance transport of piglets weaned at different ages over unpaved or paved roads	LIVESTOCK SCIENCE	2015	172		69	78
Systematic review	Medina-Vara, Martin; Guerrero-Legarreta, Isabel; Roldan-Santiago, Patricia; Castaneda-Serrano, Pilar; Gonzalez-Lozano, Miguel; Mota-Rojas, Daniel	ANIMAL WELFARE IN BROILERS: PHYSIOLOGICAL PROFILES IN RESPONSE TO TRANSPORT TO ABATTOIR, LAIRAGE AND EXSANGUINATION	REVISTA CIENTIFICA-FACULTAD DE CIENCIAS VETERINARIAS	2016	26	5	293	299
Systematic review	Messori, S.; Pedernera-Romano, C.; Magnani, D.; Rodriguez, P.; Barnard, S.; Dalmau, A.; Velarde, A.; Villa, P. Dalla	Unloading or not unloading? Sheep welfare implication of rest stop at control post after a 29 h transport	SMALL RUMINANT RESEARCH	2015	130		221	228
Systematic review	Messori, Stefano; Pedernera-Romano, Cecilia; Rodriguez, Pedro; Barnard, Shanis; Giansante, Daniele; Magnani, Diego; Dalmau, Antoni; Velarde, Antonio; Villa, Paolo Dalla	Effects of different rest-stop durations at control posts during a long journey on the welfare of sheep	VETERINARIA ITALIANA	2017	53	2	121	129
Systematic review	Minka, N. S.; Ayo, J. O.	Assessment of thermal load on transported goats administered with ascorbic acid during the hot-dry conditions	INTERNATIONAL JOURNAL OF BIOMETEOROLOGY	2012	56	2	333	341
Systematic review	Minka, N. S.; Ayo, J. O.	Effects of loading behaviour and road transport stress on traumatic injuries in cattle transported by road during the hot-dry season	LIVESTOCK SCIENCE	2007	107	1	91	95
Systematic review	Minka, N. S.; Ayo, J. O.; Sackey, A. K. B.; Adelaiye, A. B.	Assessment and scoring of stresses imposed on goats during handling, loading, road transportation and unloading, and the effect of pretreatment with ascorbic acid	LIVESTOCK SCIENCE	2009	125	2-3	275	282

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Minka, Ndazo S.; Ayo, Joseph O.	Effect of wet-cold weather transportation conditions on thermoregulation and the development of accidental hypothermia in pullets under tropical conditions	INTERNATIONAL JOURNAL OF BIOMETEOROLOGY	2016	60	3	373	380
Systematic review	Minka, Ndazo Salka; Ayo, Joseph Olusegun	Physiological and behavioral responses of goats to 12-hour road transportation, lairage and grazing periods, and the modulatory role of ascorbic acid	JOURNAL OF VETERINARY BEHAVIOR-CLINICAL APPLICATIONS AND RESEARCH	2013	8	5	349	356
Systematic review	Minka, Ndazo Salka; Ayo, Joseph Olusegun	Physiological responses of transported goats treated with ascorbic acid during the hot-dry season	ANIMAL SCIENCE JOURNAL	2007	78	2	164	172
Systematic review	Miranda-de la Lama, G. C.; Rodriguez-Palomares, M.; Cruz-Monterrosa, R. G.; Rayas-Amor, A. A.; Pinheiro, R. S. B.; Galindo, F. M.; Villarroel, M.	Long-distance transport of hair lambs: effect of location in pot-belly trailers on thermo-physiology, welfare and meat quality	TROPICAL ANIMAL HEALTH AND PRODUCTION	2018	50	2	327	336
Systematic review	Miranda-de la Lama, G. C.; Salazar-Sotelo, M. I.; Perez-Linares, C.; Figueroa-Saavedra, F.; Villarroel, M.; Sanudo, C.; Maria, G. A.	Effects of two transport systems on lamb welfare and meat quality	MEAT SCIENCE	2012	92	4	554	561
Systematic review	Mitchell, M. A.; Kettlewell, P. J.; Maxwell, M. H.	INDICATORS OF PHYSIOLOGICAL STRESS IN BROILER CHICKENS DURING ROAD TRANSPORTATION	ANIMAL WELFARE	1992	1	2	91	103
Systematic review	Mitchell, MA; Kettlewell, PJ	Physiological stress and welfare of broiler chickens in transit: Solutions not problems!	POULTRY SCIENCE	1998	77	12	1803	1814
Systematic review	Mitchell, Malcolm A.	Chick transport and welfare	AVIAN BIOLOGY RESEARCH	2009	2	1-2	99	105
Systematic review	Mota-Rojas, D.; Becerril-Herrera, M.; Roldan-Santiago, P.; Alonso-Spilsbury, M.; Flores-Peinado, S.; Ramirez-Necoechea, R.; Ramirez-Telles, J. A.; Mora-Medina, P.; Perez, M.; Molina, E.; Soni, E.; Trujillo-Ortega, M. E.	Effects of long distance transportation and CO2 stunning on critical blood values in pigs	MEAT SCIENCE	2012	90	4	893	898

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
	Munsters, C. C. B. M.; de Gooijer, J-W.; van den Broek, J.; van Oldruitenborgh-Oosterbaan, M. M. Sloet	Heart rate, heart rate variability and behaviour of horses during air transport	VETERINARY RECORD	2013	172	1	15	+
Systematic review	Nazareno, Aerica C.; da Silva, Iran J. O.; Donofre, Ana C.; Vieira, Frederico M. C.; de Castro, Ariane C.	Vibration and mechanical shocks in one day-old chicks transported in different roads	REVISTA BRASILEIRA DE ENGENHARIA AGRICOLA E AMBIENTAL	2015	19	7	680	685
Systematic review	Neves da Silva, Marco Aurello; Delfino Barbosa Filho, Jose Antonio; Mortari da Silva, Caio Jose; do Rosario, Millor Fernandes; Oliveira da Silva, Iran Jose; Domingos Coelho, Antonio Augusto; Maria Savino, Vicente Jose	Evaluation of thermal stress in simulated condition of transportation on broiler chickens	REVISTA BRASILEIRA DE ZOOTECNIA-BRAZILIAN JOURNAL OF ANIMAL SCIENCE	2007	36	4	1126	1130
Systematic review	Niedzwiedz, Artur; Kubiak, Krzysztof; Nicpon, Jozef	Plasma total antioxidant status in horses after 8-hours of road transportation	ACTA VETERINARIA SCANDINAVICA	2013	55			
Systematic review	Nielsen, B. L.; Dybkjaer, L.; Herskin, M. S.	Road transport of farm animals: effects of journey duration on animal welfare	ANIMAL	2011	5	3	415	427
Systematic review	Nijdam, E; Arens, P; Lambooij, E; Decuypere, E; Stegeman, JA	Factors influencing bruises and mortality of broilers during catching, transport, and lairage	POULTRY SCIENCE	2004	83	9	1610	1615
Systematic review	Nikbin, Saeid; Panandam, Jothi M.; Sazili, Awis Q.	Influence of pre-slaughter transportation and stocking density on carcass and meat quality characteristics of Boer goats	ITALIAN JOURNAL OF ANIMAL SCIENCE	2016	15	3	504	511
Systematic review	Norris, RT	Transport of animals by sea	REVUE SCIENTIFIQUE ET TECHNIQUE-OFFICE INTERNATIONAL DES EPIZOOTIES	2005	24	2	673	681
Systematic review	Norris, RT; Richards, RB; Creeper, JH; Jubb, TF; Madin, B; Kerr, JW	Cattle deaths during sea transport from Australia	AUSTRALIAN VETERINARY JOURNAL	2003	81	3	156	161
Systematic review	Oba, Alexandre; de Almeida, Mauricio; Pinheiro, Joao Waine; Ida, Elza Iouko; Marchi, Denis Fabricio; Soares, Adriana Lourenco; Shimokomaki, Massami	The Effect of Management of Transport and Lairage Conditions on Broiler Chicken Breast Meat Quality and DOA (Death on Arrival)	BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY	2009	52		205	211

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Ohmura, Hajime; Hobo, Seiji; Hiraga, Atsushi; Jones, James H.	Changes in heart rate and heart rate variability during transportation of horses by road and air	AMERICAN JOURNAL OF VETERINARY RESEARCH	2012	73	4	515	521
Systematic review	Oliveira Santos Godoi, Tatianne Leme; Villas-Boas, Julia Dias; dos Santos Almeida, Norma Aparecida; Trigo, Pablo Ignacio; de Almeida, Fernando Queiroz; de Medeiros, Magda Alves	Pharmacopuncture Versus Acepromazine in Stress Responses of Horses During Road Transport	JOURNAL OF EQUINE VETERINARY SCIENCE	2014	34	2	294	301
	Onmaz, A. C.; Van den Hoven, R.; Gunes, V.; Cinar, M.; Kucuk, O.	Oxidative stress in horses after a 12-hours transport period	REVUE DE MEDECINE VETERINAIRE	2011	162	4	213	217
Systematic review	Orihuela, A; Sanchez-Mejorada, H; Toledo, M	Effect of short transport during di-oestrus and pro-oestrus on cortisol levels and oestrous behaviour of sheep	JOURNAL OF AGRICULTURAL SCIENCE	2002	138		93	96
Systematic review	Padalino, B.; Raidal, S. L.; Hall, E.; Knight, P.; Celi, P.; Jeffcott, L.; Muscatello, G.	Risk factors in equine transport-related health problems: A survey of the Australian equine industry	EQUINE VETERINARY JOURNAL	2017	49	4	507	511
Systematic review	Padalino, B.; Raidal, S. L.; Hall, E.; Knight, P.; Celi, P.; Jeffcott, L.; Muscatello, G.	Survey of horse transportation in Australia: issues and practices	AUSTRALIAN VETERINARY JOURNAL	2016	94	10	349	357
Systematic review	Padalino, Barbara	Effects of the different transport phases on equine health status, behavior, and welfare: A review	Journal of Veterinary Behavior-Clinical Applications and Research	2015	10	3	272	282
Systematic review	Padalino, Barbara; Hall, Evelyn; Raidal, Sharanne; Celi, Pietro; Knight, Peter; Jeffcott, Leo; Muscatello, Gary	Health Problems and Risk Factors Associated with Long Haul Transport of Horses in Australia	ANIMALS	2015	5	4	1296	1310
Systematic review	Padalino, Barbara; Henshall, Cathrynne; Raidal, Sharanne Lee; Knight, Peter; Celi, Pietro; Jeffcott, Leo; Muscatello, Gary	Investigations Into Equine Transport-Related Problem Behaviors: Survey Results	JOURNAL OF EQUINE VETERINARY SCIENCE	2017	48		166	173
Systematic review	Padalino, Barbara; Raidal, Sharanne L.; Knight, Peter; Celi, Pietro; Jeffcott, Leo; Muscatello, Gary	Behaviour during transportation predicts stress response and lower airway contamination in horses	PLOS ONE	2018	13	3		
Systematic review	Parker, R; Watson, R; Wells, E; Brown, S; Nicol, Q; Knowles, T	The effect of blindfolding horses on heart rate and behaviour during handling and loading onto transport vehicles	ANIMAL WELFARE	2004	13	4	433	437

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Parrott, RF; Hall, SJG; Lloyd, DM	Heart rate and stress hormone responses of sheep to road transport following two different loading procedures	ANIMAL WELFARE	1998	7	3	257	267
Systematic review	Parrott, RF; Lloyd, DM; Brown, D	Transport stress and exercise hyperthermia recorded in sheep by radiotelemetry	ANIMAL WELFARE	1999	8	1	27	34
Systematic review	Pascual-Alonso, M.; Miranda-de la Lama, G. C.; Aguayo-Ulloa, L.; Villarroel, M.; Mitchell, M.; Maria, G. A.	Thermophysiological, haematological, biochemical and behavioural stress responses of sheep transported on road	JOURNAL OF ANIMAL PHYSIOLOGY AND ANIMAL NUTRITION	2017	101	3	541	551
Systematic review	Pereira, Thuanny L.; Corassa, Anderson; Komiyama, Claudia M.; Araujo, Claudio V.; Kataoka, Alessandra	The effect of transport density and gender on stress indicators and carcass and meat quality in pigs	SPANISH JOURNAL OF AGRICULTURAL RESEARCH	2015	13	3		
Systematic review	Perez, MP; Palacio, J; Santolaria, MP; Acena, MC; Chacon, G; Gascon, M; Calvo, JH; Zaragoza, P; Beltran, JA; Garcia-Belenguer, S	Effect of transport time on welfare and meat quality in pigs	MEAT SCIENCE	2002	61	4	425	433
Systematic review	Petracci, M.; Bianchi, M.; Cavani, C.	Pre-slaughter handling and slaughtering factors influencing poultry product quality	WORLDS POULTRY SCIENCE JOURNAL	2010	66	1	17	26
Systematic review	Phillips, Clive J. C.; Santurtun, Eduardo	The welfare of livestock transported by ship	VETERINARY JOURNAL	2013	196	3	309	314
Systematic review	PHILLIPS, WA; JUNIEWICZ, PE; ZAVY, MT; VONTUNGELN, DL	THE EFFECTS OF THE STRESS OF WEANING AND TRANSIT ON PERFORMANCE AND METABOLIC PROFILE OF BEEF-CALVES OF DIFFERENT GENOTYPES	CANADIAN JOURNAL OF ANIMAL SCIENCE	1987	67	4	991	999
Systematic review	Pilcher, C. M.; Ellis, M.; Rojo-Gomez, A.; Curtis, S. E.; Wolter, B. F.; Peterson, C. M.; Peterson, B. A.; Ritter, M. J.; Brinkmann, J.	Effects of floor space during transport and journey time on indicators of stress and transport losses of market-weight pigs	JOURNAL OF ANIMAL SCIENCE	2011	89	11	3809	3818
Systematic review	Pineiro, Matilde; Pineiro, Carlos; Carpintero, Rakel; Morales, Joaquin; Campbell, Fiona M.; Eckersall, P. David; Toussaint, Mathilda J. M.; Lampreave, Fermin	Characterisation of the pig acute phase protein response to road transport	VETERINARY JOURNAL	2007	173	3	669	674
Systematic review	Price, D. M.; Lewis, A. W.; Neuendorff, D. A.; Carroll, J. A.; Sanchez, N. C. Burdick; Vann, R. C.; Welsh, T. H., Jr.; Randel, R. D.	Physiological and metabolic responses of gestating Brahman cows to repeated transportation	JOURNAL OF ANIMAL SCIENCE	2015	93	2	737	745

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Probst, J. K.; Neff, A. Spengler; Hillmann, E.; Kreuzer, M.; Koch-Mathis, M.; Leiber, F.	Relationship between stress-related exsanguination blood variables, vocalisation, and stressors imposed on cattle between lairage and stunning box under conventional abattoir conditions	LIVESTOCK SCIENCE	2014	164		154	158
Systematic review	Purswell, JL; Gates, RS; Lawrence, LM; Jacob, JD; Stombaugh, TS; Coleman, RJ	Air exchange rate in a horse trailer during road transport	TRANSACTIONS OF THE ASABE	2006	49	1	193	201
Systematic review	Quinn, AD; Kettlewell, PJ; Mitchell, MA; Knowles, T	Air movement and the thermal microclimates observed in poultry lairages	BRITISH POULTRY SCIENCE	1998	39	4	469	476
Systematic review	Radisavljevic, K.; Vucinic, M.; Becskei, Zs.; Stanojkovic, A.; Ostovic, M.	Comparison of stress level indicators in blood of free-roaming dogs after transportation and housing in the new environment	JOURNAL OF APPLIED ANIMAL RESEARCH	2017	45	1	52	55
Systematic review	Rajion, MA; Saat, IM; Zulkifli, I; Goh, YM	The effects of road transportation on some physiological stress measures in goats	ASIAN-AUSTRALASIAN JOURNAL OF ANIMAL SCIENCES	2001	14	9	1250	1252
Systematic review	Richards, G. J.; Wilkins, L. J.; Weeks, C. A.; Knowles, T. G.; Brown, S. N.	Evaluation of the microclimate in poultry transport module drawers during the marketing process of end-of-lay hens from farm to slaughter	VETERINARY RECORD	2012	171	19	474	+
Systematic review	Ritter, M. J.; Ellis, M.; Bertelsen, C. R.; Bowman, R.; Brinkmann, J.; DeDecker, J. M.; Keffaber, K. K.; Murphy, C. M.; Peterson, B. A.; Schlipf, J. M.; Woltert, B. F.	Effects of distance moved during loading and floor space on the trailer during transport on losses of market weight pigs on arrival at the packing plant	JOURNAL OF ANIMAL SCIENCE	2007	85	12	3454	3461
Systematic review	Ritter, M. J.; Ellis, M.; Bowman, R.; Brinkmann, J.; Curtis, S. E.; DeDecker, J. M.; Mendoza, O.; Murphy, C. M.; Orellana, D. G.; Peterson, B. A.; Rojo, A.; Schlipf, J. M.; Wolter, B. F.	Effects of season and distance moved during loading on transport losses of market-weight pigs in two commercially available types of trailer	JOURNAL OF ANIMAL SCIENCE	2008	86	11	3137	3145
Systematic review	Ritter, M. J.; Ellis, M.; Brinkmann, J.; DeDecker, J. M.; Keffaber, K. K.; Kocher, M. E.; Peterson, B. A.; Schlipf, J. M.; Wolter, B. F.	Effect of floor space during transport of market-weight pigs on the incidence of transport losses at the packing plant and the relationships between transport conditions and losses	JOURNAL OF ANIMAL SCIENCE	2006	84	10	2856	2864

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Roldan-Santiago, P.; Martinez-Rodriguez, R.; Yanez-Pizana, A.; Trujillo-Ortega, M. E.; Sanchez-Hernandez, M.; Perez-Pedraza, E.; Mota-Rojas, D.	Stressor factors in the transport of weaned piglets: a review	VETERINARNI MEDICINA	2013	58	5	241	251
Systematic review	Roldan-Santiago, P.; Mota-Rojas, D.; Orozco-Gregorio, H.; Borderas-Tordesillas, F.; Martinez-Rodriguez, R.; Mora-Medina, P.; Flores-Peinado, S.; Sanchez-Hernandez, M.; Trujillo-Ortega, M. E.	Welfare of recently weaned piglets transported on unpaved roads: the effect of age and the use of straw bedding	ANIMAL PRODUCTION SCIENCE	2015	55	5	648	653
Systematic review	Roldan-Santiago, Patricia; Trujillo-Ortega, Maria; Borderas-Tordesillas, Fernando; Martinez-Rodriguez, Roberto; Mora-Medina, Patricia; Flores-Peinado, Salvador; Sanchez-Hernandez, Monica; Garcia-Herrera, Ricardo; Gonzalez-Lozano, Miguel; Mota-Rojas, Daniel	Physiometabolic responses to road transport in weaned piglets for a short period and the effects of straw bedding	ANIMAL SCIENCE JOURNAL	2015	86	5	563	571
Systematic review	Romero, M. H.; Uribe-Velasquez, L. F.; Sanchez, J. A.; Miranda-de la Lama, G. C.	Risk factors influencing bruising and high muscle pH in Colombian cattle carcasses due to transport and pre-slaughter operations	MEAT SCIENCE	2013	95	2	256	263
Systematic review	Ross, M.; Widowski, T. M.; Haley, D. B.	The effects of feeding space on the behavioural responses of cattle during rest periods offered as part of long-distance transportation	ANIMAL WELFARE	2016	25	2	217	225
Systematic review	Roussel, S; Hemsworth, PH; Leruste, H; White, C; Duvaux-Ponter, C; Nowak, R; Boissy, A	Repeated transport and isolation during pregnancy in ewes: Effects on the reactivity to humans and to their offspring after lambing	APPLIED ANIMAL BEHAVIOUR SCIENCE	2006	97	2-4	172	189
Systematic review	Roy, R. Cyril; Cockram, Michael S.; Dohoo, Ian R.	Welfare of horses transported to slaughter in Canada: Assessment of welfare and journey risk factors affecting welfare	CANADIAN JOURNAL OF ANIMAL SCIENCE	2015	95	4	509	522
Systematic review	Ruiz-de-la-Torre, JL; Velarde, A; Diestre, A; Gispert, M; Hall, SJG; Broom, DM; Manteca, X	Effects of vehicle movements during transport on the stress responses and meat quality of sheep	VETERINARY RECORD	2001	148	8	227	229
Systematic review	Salamano, Germana; Mellia, Elisabetta; Candiani, Denise; Ingravalle, Francesco; Bruno, Renato; Ru, Giuseppe; Doglione, Luca	Changes in haptoglobin, C-reactive protein and pig-MAP during a housing period following long distance transport in swine	VETERINARY JOURNAL	2008	177	1	110	115

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Sanchez-Sanchez, M.; Vieira-Aller, C.; De-la-Fuente-Vazquez, J.; Perez-Marcos, C.; Lauzurica-Gomez, S.; Gonzalez-de-Chavarri, E.; Diaz-Diaz-Chiron, M. T.	Effect of season and stocking density during transport on carcass and meat quality of suckling lambs	SPANISH JOURNAL OF AGRICULTURAL RESEARCH	2013	11	2	394	404
Systematic review	Santurtun, E.; Moreau, V.; Marchant-Forde, J. N.; Phillips, C. J. C.	Physiological and behavioral responses of sheep to simulated sea transport motions	JOURNAL OF ANIMAL SCIENCE	2015	93	3	1250	1257
Systematic review	Santurtun, Eduardo; Moreau, Valerie; Phillips, Clive J. C.	A novel method to measure the impact of sea transport motion on sheep welfare	BIOSYSTEMS ENGINEERING	2014	118		128	137
Systematic review	Santurtun, Eduardo; Phillips, Clive J. C.	The impact of vehicle motion during transport on animal welfare	RESEARCH IN VETERINARY SCIENCE	2015	100		303	308
Systematic review	Sariozkan, Savas; Cevger, Yavuz; Aral, Yilmaz	Effects of road transport on yearling lambs up to 19 hours	ANKARA UNIVERSITESI VETERINER FAKULTESI DERGISI	2009	56	3	215	218
Systematic review	Sariozkan, Savas; Cevger, Yavuz; Kucuk, Osman; Aral, Yilmaz	Different Effects of Road Transport on Yearling Lambs	KAFKAS UNIVERSITESI VETERINER FAKULTESI DERGISI	2009	15	5	705	708
Systematic review	Schmidt, A.; Biau, S.; Moestl, E.; Becker-Birck, M.; Morillon, B.; Aurich, J.; Faure, J. -M.; Aurich, C.	Changes in cortisol release and heart rate variability in sport horses during long-distance road transport	DOMESTIC ANIMAL ENDOCRINOLOGY	2010	38	3	179	189
Systematic review	Schmidt, A.; Hoedl, S.; Moestl, E.; Aurich, J.; Mueller, J.; Aurich, C.	Cortisol release, heart rate, and heart rate variability in transport-naive horses during repeated road transport	DOMESTIC ANIMAL ENDOCRINOLOGY	2010	39	3	205	213
Systematic review	Schmidt, Alice; Moestl, Erich; Wehnert, Christiane; Aurich, Joerg; Mueller, Juergen; Aurich, Christine	Cortisol release and heart rate variability in horses during road transport	HORMONES AND BEHAVIOR	2010	57	2	209	215
Systematic review	Schrama, JW; vanderHel, W; Gorssen, J; Henken, AM; Verstegen, MWA; Noordhuizen, JPTM	Required thermal thresholds during transport of animals	VETERINARY QUARTERLY	1996	18	3	90	95
Systematic review	Schwartzkopf-Genswein, K. S.; Faucitano, L.; Dadgar, S.; Shand, P.; Gonzalez, L. A.; Crowe, T. G.	Road transport of cattle, swine and poultry in North America and its impact on animal welfare, carcass and meat quality: A review	MEAT SCIENCE	2012	92	3	227	243

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Schwartzkopf-Genswein, Karen Shelley; Booth-McLean, Mary Elizabeth; Shah, Mohammad Abid; Entz, Toby; Bach, Susan Joan; Mears, Gerald John; Schaefer, Allan Lee; Cook, Nigel; Church, John; McAllister, Tim Angus	Effects of pre-haul management and transport duration on beef calf performance and welfare	APPLIED ANIMAL BEHAVIOUR SCIENCE	2007	108	1-2	12	30
Systematic review	Sherlock, Louise; Wathes, Christopher M.; Cheng, Zhangrui; Wathes, D. Claire	Differential hepatic gene expression in the broiler chicken in response to the combined stressors of food withdrawal, catching and transport at the end of production	STRESS-THE INTERNATIONAL JOURNAL ON THE BIOLOGY OF STRESS	2012	15	3	293	305
Systematic review	Simoes, Gislaine Silveira; Oba, Alexandre; Matsuo, Tiemi; Rossa, Alessandro; Shimokomaki, Massami; Ida, Elza Iouko	Vehicle Thermal Microclimate Evaluation during Brazilian Summer Broiler Transport and the Occurrence of PSE (Pale, Soft, Exudative) Meat	BRAZILIAN ARCHIVES OF BIOLOGY AND TECHNOLOGY	2009	52		195	204
Systematic review	Simova, Veronika; Vecerek, Vladimir; Passantino, Annamaria; Voslarova, Eva	Pre-transport factors affecting the welfare of cattle during road transport for slaughter - a review	ACTA VETERINARIA BRNO	2016	85	3	303	318
Systematic review	Simova, Veronika; Voslarova, Eva; Vecerek, Vladimir; Passantino, Annamaria; Bedanova, Iveta	Effects of travel distance and season of the year on transport-related mortality in cattle	ANIMAL SCIENCE JOURNAL	2017	88	3	526	532
Systematic review	Smiecinska, K.; Denaburski, J.; Sobotka, W.	Slaughter value, meat quality, creatine kinase activity and cortisol levels in the blood serum of growing-finishing pigs slaughtered immediately after transport and after a rest period	POLISH JOURNAL OF VETERINARY SCIENCES	2011	14	1	47	54
Systematic review	SMITH, BL; JONES, JH; CARLSON, GP; PASCOE, JR	BODY POSITION AND DIRECTION PREFERENCES IN HORSES DURING ROAD TRANSPORT	EQUINE VETERINARY JOURNAL	1994	26	5	374	377
Systematic review	Soler, L.; Gutierrez, A.; Escribano, D.; Fuentes, M.; Ceron, J. J.	Response of salivary haptoglobin and serum amyloid A to social isolation and short road transport stress in pigs	RESEARCH IN VETERINARY SCIENCE	2013	95	1	298	302
Systematic review	Sommavilla, Roberta; Faucitano, Luigi; Gonyou, Harold; Seddon, Yolande; Bergeron, Renee; Widowski, Tina; Crowe, Trever; Connor, Laurie; Scheeren, Marina Bergoli; Goumon, Sebastien; Brown, Jennifer	Season, Transport Duration and Trailer Compartment Effects on Blood Stress Indicators in Pigs: Relationship to Environmental, Behavioral and Other Physiological Factors, and Pork Quality Traits	ANIMALS	2017	7	2		

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Sommavilla, Roberta; Faucitano, Luigi; Gonyou, Harold; Seddon, Yolande; Bergeron, Renee; Widowski, Tina; Crowe, Trever; Connor, Laurie; Scheeren, Marina Bergoli; Goumon, Sebastien; Brown, Jennifer	Season, Transport Duration and Trailer Compartment Effects on Blood Stress Indicators in Pigs: Relationship to Environmental, Behavioral and Other Physiological Factors, and Pork Quality Traits (vol 7, 8, 2017)	ANIMALS	2017	7	3		
Systematic review	Sowinska, Janina; Brzostowski, Henryk; Tanski, Zenon; Lisowska, Joanna	Stress reaction of lambs to weaning and short transport to slaughterhouse with regards to the breed and age	MEDYCYNA WETERYNARYJNA	2006	62	8	946	948
Systematic review	Sowinska, Janina; Wojcik, Anna; Pomianowski, Janusz F.; Chorazy, Lukasz; Mituniewicz, Tomasz; Witkowska, Dorota; Piotrowska, Joanna; Kwiatkowska-Stenzel, Agnieszka; Czaplinska, Barbara; Kuczynska, Paulina	Effects of different variants of pre-slaughter transport on body weight loss and meat quality in broiler chickens	MEDYCYNA WETERYNARYJNA	2013	69	7	420	423
Systematic review	Sporer, K. R. Buckham; Weber, P. S. D.; Burton, J. L.; Earley, B.; Crowe, M. A.	Transportation of young beef bulls alters circulating physiological parameters that may be effective biomarkers of stress	JOURNAL OF ANIMAL SCIENCE	2008	86	6	1325	1334
Systematic review	Spurio, Rafael S.; Soares, Adriana L.; Carvalho, Rafael H.; Silveira Junior, Vivaldo; Grespan, Moises; Oba, Alexandre; Shimokomaki, Massami	Improving transport container design to reduce broiler chicken PSE (pale, soft, exudative) meat in Brazil	ANIMAL SCIENCE JOURNAL	2016	87	2	277	283
Systematic review	Stewart, M; Foster, TM; Waas, JR	The effects of air transport on the behaviour and heart rate of horses	APPLIED ANIMAL BEHAVIOUR SCIENCE	2003	80	2	143	160
Systematic review	Stockman, C. A.; Collins, T.; Barnes, A. L.; Miller, D.; Wickham, S. L.; Beatty, D. T.; Blache, D.; Wemelsfelder, F.; Fleming, P. A.	Qualitative behavioural assessment and quantitative physiological measurement of cattle naive and habituated to road transport	ANIMAL PRODUCTION SCIENCE	2011	51	3	240	249
Systematic review	Strawford, M. L.; Watts, J. M.; Crowe, T. C.; Classen, H. L.; Shand, P. J.	The effect of simulated cold weather transport on core body temperature and behavior of broilers	POULTRY SCIENCE	2011	90	11	2415	2424
Systematic review	Sutherland, M. A.; Bryer, P. J.; Davis, B. L.; McGlone, J. J.	Space requirements of weaned pigs during a sixty-minute transport in summer	JOURNAL OF ANIMAL SCIENCE	2009	87	1	363	370

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Sutherland, M. A.; Krebs, N.; Smith, J. S.; Dailey, J. W.; Carroll, J. A.; McGlone, J. J.	The effect of three space allowances on the physiology and behavior of weaned pigs during transportation	LIVESTOCK SCIENCE	2009	126	1-3	183	188
Systematic review	TARRANT, PV	THE EFFECTS OF HANDLING, TRANSPORT, SLAUGHTER AND CHILLING ON MEAT QUALITY AND YIELD IN PIGS - A REVIEW	IRISH JOURNAL OF FOOD SCIENCE AND TECHNOLOGY	1989	13	2	79	107
Systematic review	Taylor, NL; Fletcher, DL; Northcutt, JK; Lacy, MP	Effect of transport cage height on broiler live shrink and defecation patterns	JOURNAL OF APPLIED POULTRY RESEARCH	2001	10	4	335	339
Systematic review	Theurer, Miles E.; White, Brad J.; Anderson, David E.; Miesner, Matt D.; Mosier, Derek A.; Coetzee, Johann E.; Amrine, David E.	Effect of transportation during periods of high ambient temperature on physiologic and behavioral indices of beef heifers	AMERICAN JOURNAL OF VETERINARY RESEARCH	2013	74	3	481	490
Systematic review	Thomsen, P. T.; Sorensen, J. T.	Does short-term road transport affect the locomotion score of dairy cows?	ANIMAL WELFARE	2013	22	4	445	447
Systematic review	Thornton, J	Effect of the microclimate on horses during international air transportation in an enclosed container	AUSTRALIAN VETERINARY JOURNAL	2000	78	7	472	477
Systematic review	Torrey, S.; Bergeron, R.; Faucitano, L.; Widowski, T.; Lewis, N.; Crowe, T.; Correa, J. A.; Brown, J.; Hayne, S.; Gonyou, H. W.	Transportation of market-weight pigs: II. Effect of season and location within truck on behavior with an eight-hour transport	JOURNAL OF ANIMAL SCIENCE	2013	91	6	2872	2878
Systematic review	Torrey, S.; Bergeron, R.; Widowski, T.; Lewis, N.; Crowe, T.; Correa, J. A.; Brown, J.; Gonyou, H. W.; Faucitano, L.	Transportation of market-weight pigs: I. Effect of season, truck type, and location within truck on behavior with a two-hour transport	JOURNAL OF ANIMAL SCIENCE	2013	91	6	2863	2871
Systematic review	Toscano, MJ; Friend, TH	A note on the effects of forward and rear-facing orientations on movement of horses during transport	APPLIED ANIMAL BEHAVIOUR SCIENCE	2001	73	4	281	287
Systematic review	Valros, Anna; Vuorenrnaa, Reeta; Janczak, Andrew M.	Effect of simulated long transport on behavioural characteristics in two strains of laying hen chicks	APPLIED ANIMAL BEHAVIOUR SCIENCE	2008	109	1	58	67
Systematic review	van Staaveren, Nienke; Teixeira, Dayane Lemos; Hanlon, Alison; Boyle, Laura Ann	The Effect of Mixing Entire Male Pigs Prior to Transport to Slaughter on Behaviour, Welfare and Carcass Lesions	PLOS ONE	2015	10	4		

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Vecerek, V.; Grbalova, S.; Voslarova, E.; Janackova, B.; Malena, M.	Effects of travel distance and the season of the year on death rates of broilers transported to poultry processing plants	POULTRY SCIENCE	2006	85	11	1881	1884
Systematic review	Vecerek, V.; Malena, M., Jr.; Malena, M.; Voslarova, E.; Bedanova, I.	Mortality in dairy cows transported to slaughter as affected by travel distance and seasonality	ACTA VETERINARIA BRNO	2006	75	3	449	454
Systematic review	Vecerek, V.; Simova, V.; Malena, M.; Voslarova, E.; Malena, M., Jr.	Effect of calf diseases on mortality during transport for slaughter	ACTA VETERINARIA BRNO	2006	75	4	625	630
Systematic review	Vecerek, V; Malena, M; Malena, M; Voslarova, E; Chloupek, P	The impact of the transport distance and season on losses of fattened pigs during transport to the slaughterhouse in the Czech Republic in the period from 1997 to 2004	VETERINARNI MEDICINA	2006	51	1	21	28
Systematic review	Vecerek, Vladimir; Voslarova, Eva; Conte, Francesca; Vecerkova, Lenka; Bedanova, Iveta	Negative Trends in Transport-related Mortality Rates in Broiler Chickens	ASIAN-AUSTRALASIAN JOURNAL OF ANIMAL SCIENCES	2016	29	12	1796	1804
Systematic review	Vermette, C. J.; Henrikson, Z. A.; Schwean-Lardner, K. V.; Crowe, T. G.	Influence of hot exposure on 12-week-old turkey hen physiology, welfare, and meat quality and 16-week-old turkey tom core body temperature when crated at transport density	POULTRY SCIENCE	2017	96	11	3836	3843
Systematic review	Vieira, F. M. C.; Silva, I. J. O.; Filho, J. A. D. Barbosa; Vieira, A. M. C.; Broom, D. M.	Preslaughter mortality of broilers in relation to lairage and season in a subtropical climate	POULTRY SCIENCE	2011	90	10	2127	2133
Systematic review	Vieira, F. M. C.; Silva, I. J. O.; Nazareno, A. C.; Faria, P. N.; Miranda, K. O. S.	Thermoregulation of day-old chickens submitted to simulated transport thermal environment	ARQUIVO BRASILEIRO DE MEDICINA VETERINARIA E ZOOTECNIA	2016	68	1	208	214
Systematic review	Villarroel, Morris; Barreiro, Pilar; Kettlewell, Peter; Farish, Marianne; Mitchell, Malcolm	Time derivatives in air temperature and enthalpy as non-invasive welfare indicators during long distance animal transport	BIOSYSTEMS ENGINEERING	2011	110	3	253	260
Systematic review	Vinco, Leonardo James; Archetti, Ivonne Laura; Giacomelli, Stefano; Lombardi, Guerino	Influence of crate height on the welfare of broilers during transport	JOURNAL OF VETERINARY BEHAVIOR-CLINICAL APPLICATIONS AND RESEARCH	2016	14		28	33

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	von Borell, E; Schaffer, D	Legal requirements and assessment of stress and welfare during transportation and pre-slaughter handling of pigs	LIVESTOCK PRODUCTION SCIENCE	2005	97	2-3	81	87
Systematic review	Voslarova, E.; Chloupek, P.; Vosmerova, P.; Chloupek, J.; Bedanova, I.; Vecerek, V.	Time course changes in selected biochemical indices of broilers in response to pretransport handling	POULTRY SCIENCE	2011	90	10	2144	2152
Systematic review	Voslarova, E.; Janackova, B.; Rubesova, L.; Kozak, A.; Bedanova, I.; Steinhauser, L.; Vecerek, V.	Mortality rates in poultry species and categories during transport for slaughter	ACTA VETERINARIA BRNO	2007	76		S101	S108
Systematic review	Voslarova, E.; Janackova, B.; Vitula, F.; Kozak, A.; Vecerek, V.	Effects of transport distance and the season of the year on death rates among hens and roosters in transport to poultry processing plants in the Czech Republic in the period from 1997 to 2004	VETERINARNI MEDICINA	2007	52	6	262	266
Systematic review	Voslarova, Eva; Chloupek, Petr; Steinhauser, Ladislav; Havlicek, Jan; Vecerek, Vladimir	Influence of Housing System and Number of Transported Animals on Transport-induced Mortality in Slaughter Pigs	ACTA VETERINARIA BRNO	2010	79		S79	S84
Systematic review	Voslarova, Eva; Hytychova, Tat'ana; Vecerek, Vladimir; Nenadovic, Katarina; Bedanova, Iveta	Transport-induced mortality in Pekin ducks transported for slaughter in the Czech Republic	ACTA VETERINARIA BRNO	2016	85	2	205	212
Systematic review	Vosmerova, P.; Chloupek, J.; Bedanova, I.; Chloupek, P.; Kruzikova, K.; Blahova, J.; Vecerek, V.	Changes in selected biochemical indices related to transport of broilers to slaughterhouse under different ambient temperatures	POULTRY SCIENCE	2010	89	12	2719	2725
Systematic review	Vosmerova, Petra; Bedanova, Iveta; Chloupek, Petr; Chloupek, Jan; Suchy, Pavel, Jr.; Vecerek, Vladimir	Transport-induced Changes in Selected Biochemical Indices in Broilers as Affected by Ambient Temperatures	ACTA VETERINARIA BRNO	2010	79		S41	S46
Systematic review	Wamnes, S.; Lewis, N. J.; Berry, R. J.	The behaviour of early-weaned piglets following transport: Effect of season and weaning weight	CANADIAN JOURNAL OF ANIMAL SCIENCE	2008	88	3	357	367
Systematic review	WARAN, NK; CUDDEFORD, D	EFFECTS OF LOADING AND TRANSPORT ON THE HEART-RATE AND BEHAVIOR OF HORSES	APPLIED ANIMAL BEHAVIOUR SCIENCE	1995	43	2	71	81
Systematic review	Waran, NK; Robertson, V; Cuddeford, D; Kokoszko, A; Marlin, DJ	Effects of transporting horses facing either forwards or backwards on their behaviour and heart rate	VETERINARY RECORD	1996	139	1	7	11

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Warren, Laura A.; Mandell, Ira B.; Bateman, Ken G.	An audit of transport conditions and arrival status of slaughter cattle shipped by road at an Ontario processor	CANADIAN JOURNAL OF ANIMAL SCIENCE	2010	90	2	159	167
Systematic review	Warriss, PD; Brown, SN; Knowles, IG; Wilkins, LJ; Pope, SJ; Chadd, SA; Kettlewell, PJ; Green, NR	Comparison of the effects of fan-assisted and natural ventilation of vehicles on the welfare of pigs being transported to slaughter	VETERINARY RECORD	2006	158	17	585	588
Systematic review	Warriss, PD; Brown, SN; Knowles, TG; Edwards, JE; Kettlewell, PJ; Guise, HJ	The effect of stocking density in transit on the carcass quality and welfare of slaughter pigs: 2. Results from the analysis of blood and meat samples	MEAT SCIENCE	1998	50	4	447	456
Systematic review	WARRISS, PD; BROWN, SN; KNOWLES, TG; KESTIN, SC; EDWARDS, JE; DOLAN, SK	EFFECTS ON CATTLE OF TRANSPORT BY ROAD FOR UP TO 15 HOURS	VETERINARY RECORD	1995	136	13	319	323
Systematic review	Warriss, PD; Edwards, JE; Brown, SN; Knowles, TG	Survey of the stocking densities at which sheep are transported commercially in the United Kingdom	VETERINARY RECORD	2002	150	8	233	236
Systematic review	Warriss, PD; Knowles, TG; Brown, SN; Edwards, JE; Kettlewell, PJ; Mitchell, MA; Baxter, CA	Effects of lairage time on body temperature and glycogen reserves of broiler chickens held in transport modules	VETERINARY RECORD	1999	145	8	218	222
Systematic review	Weeks, C. A.	A review of welfare in cattle, sheep and pig lairages, with emphasis on stocking rates, ventilation and noise	ANIMAL WELFARE	2008	17	3	275	284
Systematic review	Weeks, C. A.; McGreevy, P.; Waran, N. K.	Welfare issues related to transport and handling of both trained and unhandled horses and ponies	EQUINE VETERINARY EDUCATION	2012	24	8	423	430
Systematic review	Weeks, CA; McNally, PW; Warriss, PD	Influence of the design of facilities at auction markets and animal handling procedures on bruising in cattle	VETERINARY RECORD	2002	150	24	743	748
Systematic review	Weeks, CA; Webster, AJF; Wyld, HM	Vehicle design and thermal comfort of poultry in transit	BRITISH POULTRY SCIENCE	1997	38	5	464	474
Systematic review	Wein, Yossi; Geva, Zohar; Bar-Shira, Enav; Friedman, Aharon	Transport-related stress and its resolution in turkey pullets: activation of a pro-inflammatory response in peripheral blood leukocytes	POULTRY SCIENCE	2017	96	8	2601	2613

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Werner, C.; Reiners, K.; Wicke, M.	Short as well as long transport duration can affect the welfare of slaughter pigs	ANIMAL WELFARE	2007	16	3	385	389
Systematic review	Werner, Marianne; Hepp, Christian; Soto, Cristian; Gallardo, Paz; Bustamante, Hedie; Gallo, Carmen	Effects of a long distance transport and subsequent recovery in recently weaned crossbred beef calves in Southern Chile	LIVESTOCK SCIENCE	2013	152	1	42	46
Systematic review	Weschenfelder, A. V.; Torrey, S.; Devillers, N.; Crowe, T.; Bassols, A.; Saco, Y.; Pineiro, M.; Saucier, L.; Faucitano, L.	Effects of trailer design on animal welfare parameters and carcass and meat quality of three Pietrain crosses being transported over a short distance	LIVESTOCK SCIENCE	2013	157	1	234	244
Systematic review	Weschenfelder, A. V.; Torrey, S.; Devillers, N.; Crowe, T.; Bassols, A.; Saco, Y.; Pineiro, M.; Saucier, L.; Faucitano, L.	Effects of trailer design on animal welfare parameters and carcass and meat quality of three Pietrain crosses being transported over a long distance	JOURNAL OF ANIMAL SCIENCE	2012	90	9	3220	3231
Systematic review	White, B. J.; Blasi, D.; Vogel, L. C.; Epp, M.	Associations of beef calf wellness and body weight gain with internal location in a truck during transportation	JOURNAL OF ANIMAL SCIENCE	2009	87	12	4143	4150
Systematic review	Whiting, Terry L.; Drain, Mairead E.; Rasali, Drona P.	Warm weather transport of broiler chickens in Manitoba. II. Truck management factors associated with death loss in transit to slaughter	CANADIAN VETERINARY JOURNAL-REVUE VETERINAIRE CANADIENNE	2007	48	2	148	154
Systematic review	Whiting, TL; Brandt, S	Minimum space allowance for transportation of swine by road	CANADIAN VETERINARY JOURNAL-REVUE VETERINAIRE CANADIENNE	2002	43	3	207	212
Systematic review	Wichman, A.; Norring, M.; Voutila, L.; Pastell, M.; Valros, A.; Algers, B.; Hanninen, L.	Influence of crate height during slaughter transport on the welfare of male turkeys	BRITISH POULTRY SCIENCE	2012	53	4	414	420
Systematic review	Wickham, S. L.; Collins, T.; Barnes, A. L.; Miller, D. W.; Beatty, D. T.; Stockman, C.; Blache, D.; Wemelsfelder, F.; Fleming, P. A.	Qualitative behavioral assessment of transport-naive and transport-habituated sheep	JOURNAL OF ANIMAL SCIENCE	2012	90	12	4523	4535
Systematic review	Xin, H; Lee, K	Use of Aqua-Jel(R) and feed for nutrient supply during long journey air transport of baby chicks	TRANSACTIONS OF THE ASAE	1996	39	3	1123	1126

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Xing, T.; Xu, X. L.; Zhou, G. H.; Wang, P.; Jiang, N. N.	The effect of transportation of broilers during summer on the expression of heat shock protein 70, postmortem metabolism and meat quality	JOURNAL OF ANIMAL SCIENCE	2015	93	1	62	70
Systematic review	Xiong, Yijie; Green, Angela; Gates, Richard S.	Characteristics of Trailer Thermal Environment during Commercial Swine Transport Managed under US Industry Guidelines	ANIMALS	2015	5	2	226	244
Systematic review	Yalcin, S.; Guler, H. C.	Interaction of transport distance and body weight on preslaughter stress and breast meat quality of broilers	BRITISH POULTRY SCIENCE	2012	53	2	175	182
Systematic review	Yu, Jimian; Tang, Shu; Bao, Endong; Zhang, Miao; Hao, Qingqing; Yue, Zhenghua	The effect of transportation on the expression of heat shock proteins and meat quality of M. longissimus dorsi in pigs	MEAT SCIENCE	2009	83	3	474	478
Systematic review	Yue, H. Y.; Zhang, L.; Wu, S. G.; Xu, L.; Zhang, H. J.; Qi, G. H.	Effects of transport stress on blood metabolism, glycolytic potential, and meat quality in meat-type yellow-feathered chickens	POULTRY SCIENCE	2010	89	3	413	419
Systematic review	Zhang, L.; Yue, H. Y.; Wu, S. G.; Xu, L.; Zhang, H. J.; Yan, H. J.; Cao, Y. L.; Gong, Y. S.; Qi, G. H.	Transport stress in broilers. II. Superoxide production, adenosine phosphate concentrations, and mRNA levels of avian uncoupling protein, avian adenine nucleotide translocator, and avian peroxisome proliferator-activated receptor-gamma coactivator-1 alpha in skeletal muscles	POULTRY SCIENCE	2010	89	3	393	400
Systematic review	Zhang, L.; Yue, H. Y.; Zhang, H. J.; Xu, L.; Wu, S. G.; Yan, H. J.; Gong, Y. S.; Qi, G. H.	Transport stress in broilers: I. Blood metabolism, glycolytic potential, and meat quality	POULTRY SCIENCE	2009	88	10	2033	2041
Systematic review	Zhao, Y.; Xin, H.; Harmon, J. D.; Baas, T. J.	MORTALITY RATE OF WEANED AND FEEDER PIGS AS AFFECTED BY GROUND TRANSPORT CONDITIONS	Transactions of the ASABE	2016	59	4	943	948
Systematic review	Zhu, Zhen; Chen, Yang; Huang, Zhengyang; Zhang, Yang; Xu, Qi; Tong, Yiyu; Zhai, Fei; Chang, Guobin; Chen, Guohong	Effects of transport stress and rest before slaughter on blood parameters and meat quality of ducks	CANADIAN JOURNAL OF ANIMAL SCIENCE	2014	94	4	595	600
Systematic review	Zulkifli, I; Norma, MTC; Chong, CH; Loh, TC	The effects of crating and road transportation on stress and fear responses of broiler chickens treated with ascorbic acid	ARCHIV FUR GEFLUGELKUNDE	2001	65	1	33	37

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Systematic review	Zulkifli, I; Norma, MTC; Chong, CH; Loh, TC	Heterophil to lymphocyte ratio and tonic immobility reactions to preslaughter handling in broiler chickens treated with ascorbic acid	POULTRY SCIENCE	2000	79	3	402	406
Systematic review	Zulkifli, Idrus; Norbaiyah, Bahyuddin; Cheah, Yuen Wai; Soleimani, Abdoreza Farjam; Sazili, Awis Qurni; Rajion, Mohamed Ali; Goh, Yong Meng	Physiological Responses in Goats Subjected to Road Transportation under the Hot, Humid Tropical Conditions	INTERNATIONAL JOURNAL OF AGRICULTURE AND BIOLOGY	2010	12	6	840	844
	Zurbrigg, Kathy; van Dreumel, Tony; Rothschild, Max; Alves, David; Friendship, Robert; O'Sullivan, Terri	Pig-level risk factors for in-transit losses in swine: a review	CANADIAN JOURNAL OF ANIMAL SCIENCE	2017	97	3	339	346
Narrative (additional literature)	M.S. Herskin☐, A. Hels, I. Anneberg, P.T. Thomsen	Livestock drivers' knowledge about dairy cow fitness for transport – A Danish questionnaire survey	Research in Veterinary Science	2017	113		62	66
Narrative (additional literature)	Bulent Teke a,☐, Filiz Akdag a, Bulent Ekiz b, Mustafa Ugurlu a	Effects of different lairage times after long distance transportation on carcass and meat quality characteristics of Hungarian Simmental bulls	Meat Science	2014	96		224	229
Narrative (additional literature)	Satoshi TAKEMOTO,1,2 Shozo TOMONAGA,2 Masayuki FUNABA2 and Tohru MATSUI2	Effect of long-distance transportation on serum metabolic profiles of steer calves	Animal Science	2017	88		1970	1978
Narrative (additional literature)	Wambui JM1*, Lamuka PO1, Karuri EG1, Matofari JW2 and KA Abey 3	DESIGN OF TRUCKS FOR LONG DISTANCE TRANSPORTATION OF DESIGN OF TRUCKS FOR LONG DISTANCE TRANSPORTATION OF DESIGN OF TRUCKS FOR LONG DISTANCE TRANSPORTATION OF	African Journal of Food, Agriculture, Nutrition and Development	2016			3	16
Narrative (additional literature)	Tomás Norton a,⇑, Peter Kettlewell b, Malcolm Mitchell c	A computational analysis of a fully-stocked dual-mode ventilated livestock vehicle during ferry transportation	Computers and Electronics in Agriculture	2013	93		217	228
Narrative (additional literature)	Jan Broucek & Peter Kisac & Michael Uhrincat	Effect of hot temperatures on the hematological parameters, health and performance of calves	Int J Biometeorol	2009	53		201	208
Narrative (additional literature)	D. Bernardini, G. Gerardi, A. Peli, L. Nanni Costa, M. Amadori and S. Segato	The effects of different environmental conditions on thermoregulation and clinical and hematological variables in long-distance road-transported calves	Journal of Animal Science	2012	90		1183	1191

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	B. Earley†, K. Buckham Sporer and S. Gupta	Invited review: Relationship between cattle transport, immunity and respiratory disease	Animal	2017	11	3	486	492
Narrative (additional literature)	Nobue KANEMATSU, Reiji AOKI, Hiroyuki SHINGU, Tsutomu ASADA, Naoko MORIYA, Yosuke KOBAYASHI, Fumihiro OHTANI, Madoka SUTOH	Change in lymphocyte subsets of holstein calves caused by short-term transportation	Japan Agricultural Research Quarterly	2017	51	2	165	169
Narrative (additional literature)	Natyieli Losada-Espinosaa, Morris Villarroelb, Gustavo A. Maríac, Genaro C. Miranda-de la Lama	Pre-slaughter cattle welfare indicators for use in commercial abattoirs with voluntary monitoring systems: A systematic review	Meat Science	2018	138		34	48
Narrative (additional literature)	Paulo Ricardo de Oliveira Paes1*; Roberto Calderon Gonçalves2; Graziela Barioni3;Fabiola de Oliveira Paes Leme1; Marília Martins Melo1; Mariângela Lozano Cruz4	The leukogram as an indicator stress on weaning and after road transport in Nelore calfs	Semina: Ciências Agrárias, Londrina	2012	33	1	305	312
Narrative (additional literature)	Y.Z. Njisane & V. Muchenje	Pre-slaughter effects on bleed-out times and some behavioural and physiological responses of Nguni and non-descript steers	South African Journal of Animal Science	2017	47	1	79	90
Narrative (additional literature)	Andrzej Wernicki, Renata Urban-Chmiel, Andrzej Puchalski, Marta Dec	Evaluation of the influence of transport and adaptation stress on chosen immune and oxidative parameters and occurrence of respiratory syndrome in feedlot calves	Bull Vet Inst Pulawy	2014	58		111	116
Narrative (additional literature)	A.-Y. Chulayo1,2 and V. Muchenje1	Activities of some stress enzymes as indicators of slaughter cattle welfare and their relationship with physico-chemical characteristics of beef	Animal	2017			1	8
Narrative (additional literature)	A. Pineda,* M. A. Ballou,† J. M. Campbell,‡ F. C. Cardoso,* and J. K. Drackley*1	Evaluation of serum protein-based arrival formula and serum protein supplement (Gammulin) on growth, morbidity, and mortality of stressed (transport and cold) male dairy calves	J. Dairy Sci.	2016	99		9027	9039
Narrative (additional literature)	Barbara Padalino a,b,c,☐, Sharanne Lee Raidal c, Nicole Carter a, Pietro Celi d,e, Gary Muscatello a, Leo Jeffcott a, Kumudika de Silva	Immunological, clinical, haematological and oxidative responses to long distance transportation in horses	Research in Veterinary Science	2017	115		78	87

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	Ana Paula de Assis Maia1*, Stanley Robson de Medeiros Oliveira1,2, Daniella Jorge de Moura1, Juliana Sarubbi3, Rimena do Amaral Vercellino1, Brenda Batista Lemos Medeiros1, Paulo Roberto Griska4	A decision-tree-based model for evaluating the thermal comfort of horses	Scientia Agricola	2012	70	6	377	383
Narrative (additional literature)	Maria Rizzo a, Francesca Arfuso a, Claudia Giannetto a, Elisabetta Giudice b, Francesco Longo c, Simona Di Pietro a, Giuseppe Piccione a,*	Cortisol levels and leukocyte population values in transported and exercised horses after acupuncture needle stimulation	Journal of Veterinary Behavior	2017	18		56	61
Narrative (additional literature)	Maria Rizzo a, Francesca Arfuso a, Claudia Giannetto a, Elisabetta Giudice b, Francesco Longo c, Simona Di Pietro a, Giuseppe Piccione a,*	Acupuncture Needle Stimulation on Some Physiological Parameters After Road Transport and Physical Exercise in Horse	Journal of Equine Veterinary Science	2017	48		23	30
Narrative (additional literature)	S Messori*†, EK Visser‡, M Buonanno†, P Ferrari§, S Barnard†, M Borciani§ and N Ferri†	A tool for the evaluation of slaughter horse welfare during unloading	Animal Welfare	2016	25		101	113
Narrative (additional literature)	Shaobo Zhen a,b, Yiren Liu c, Xingmin Li a, Keshan Ge a, Hui Chen a, Chun Li a, Fazheng Ren a,☐	Effects of lairage time on welfare indicators, energy metabolism and meat quality of pigs in Beijing	Meat Science	2013	93		287	291
Narrative (additional literature)	L. Vermeulen a,☐, V. Van de Perre a, L. Permentier a, S. De Bie b, G. Verbeke c, R. Geers a	Pre-slaughter handling and pork quality	Meat Science	2015	100		118	123
Narrative (additional literature)	P. Roldan-Santiago1, D. Mota-Rojas2, I. Guerreo-Legarreta3,	Animal welfare of barrows with different antemortem lairage times without food	Veterinarni Medicina	2013	58	6	305	311
Narrative (additional literature)	SIVANILZA T. MACHADO1*, IRENILZA DE A. NÄÄS2, MARIO MOLLO NETO3	EFFECT OF TRANSPORTA TION DISTANCE ON WEIGHT LOSSES IN PIGS FROM DEHYDRATION	Journal of the Brazilian Association of Agricultural Enigineering	2016	36	6	1229	1238
Narrative (additional literature)	Eva Voslarova1,*, Vladimir Vecerek1, Annamaria Passantino2, Petr Chloupek3, and Iveta Bedanova1	Transport losses in finisher pigs: impact of transport distance and season of the year	Asian-Australas J Anim Sci	2017	30	1	119	124
Narrative (additional literature)	Jorge A. Correa 1,2,†, Harold Gonyou 3, Stephanie Torrey 4,‡, Tina Widowski 5, Renée Bergeron 6, Trever Crowe 7, Jean-Paul Laforest 2 and Luigi Faucitano	Welfare of Pigs Being Transported over Long Distances Using a Pot-Belly Trailer during Winter and Summer	Animals	2014	4		200	213

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	A. V. Weschenfelder,*† S. Torrey,*2 N. Devillers,* T. Crowe, A. Bassols,§ Y. Saco,§ M. Piñeiro,# L. Saucier,† and L. Faucitano	Effects of trailer design on animal welfare parameters and carcass and meat quality of three Pietrain crosses being transported over a long distance1	J. Anim. Sci.	2012	90		3220	3231
Narrative (additional literature)	Filipe Antônio Dalla Costa 1,2, Letícia S. Lopes 3 and Osmar Antônio Dalla Costa	Effects of the Truck Suspension System on Animal Welfare, Carcass and Meat Quality Traits in Pigs	Animals	2017	7	5	1	13
Narrative (additional literature)	Agnese Arduini 1,*, Veronica Redaelli 1, Fabio Luzi 2, Stefania Dall'Olio 1, Vincenzo Pace 3	Relationship between Deck Level, Body Surface Temperature and Carcass Damages in Italian Heavy Pigs after Short Journeys at Different Unloading Environmental Conditions	Animals	2017	7	10	1	9
Narrative (additional literature)	Rebecca Kephart 1, Anna Johnson 1,*, Avi Sapkota 2, Kenneth Stalder 1 and John McGlone	Establishing Sprinkling Requirements on Trailers Transporting Market Weight Pigs in Warm and Hot Weather	Animals	2014	4	1	1	19
Narrative (additional literature)	M. A. Sutherland, A. McDonald, J. J. McGlone	Effects of variations in the environment length of journey and type of trailer on the mortality and morbidity of pigs being transported to slaughter	Veterinary Record	2009	165		13	18
Narrative (additional literature)	F.A. Dalla Costa a,b, N. Devillers c, M.J.R. Paranhos da Costa a,b, L. Faucitanoc	Effects of applying preslaughter feed withdrawal at the abattoir on behaviour, blood parameters and meat quality in pigs	Meat Science	2016	119		89	94
Narrative (additional literature)	N. Uribe1*, C. M. Arango1, J. F. Naranjo2, A. M. Segura3, S. Henao2	RELATIONSHIP BETWEEN TRANSPORT AND NUTRITIONAL CHARACTERISTICS OF PORK MEAT FOR HUMAN CONSUMPTION IN THE VALLE DE ABURRÁ (COLOMBIA)	Rev Med Vet Zoot.	2017	64	3	22	35
Narrative (additional literature)	Thuanny Lúcia PEREIRA1; Anderson CORASSA1; Cláudia Marie KOMIYAMA1; Ana Paula Silva TON1; Ângelo POLIZEL NETO1; Cláudio Vieira de ARAÚJO1; Jessika Lucia STUANI1; Roque Murilo HONÓRIO1	THE EFFECT OF TRANSPORT DENSITY AND GENDER ON SKIN TEMPERATURE AND CARCASS AND MEAT QUALITY IN PIGS	Biosci. J.,	2017	33	6	1576	1585
Narrative (additional literature)	Samuel Aradom, Girma Gebresenbet, Fufa Sorri Bulitta, Emmanuel Yahoovie Bobobee and Musa Adam	Effect of Transport Times on Welfare of Pigs	Journal of Agricultural Science and Technology	2012	2		544	562
Narrative (additional literature)	A.M. Gutiérrez, D. Escribano, M. Fuentes, J.J. Cerón	Circadian pattern of acute phase proteins in the saliva of growing pigs	The Veterinary Journal	2013	196		167	170

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	M. Dokmanović a,☐, A. Velarde b, V. Tomović c, N. Glamočlija a, R. Marković a, J. Janjić a, M.Ž. Baltić a	The effects of lairage time and handling procedure prior to slaughter on stress and meat quality parameters in pigs	MEAT SCIENCE	2014	98		220	226
Narrative (additional literature)	Pia Brandt a,b,☐, Margit Dall Aaslyng b	Welfaremeasurements of finishing pigs on the day of slaughter: A review	MEAT SCIENCE	2015	103		13	23
Narrative (additional literature)	N. Jama a, V.Maphosa a, L.C. Hoffman b, V. Muchenje a,☐	Effect of sex and time to slaughter (transportation and lairage duration) on the levels of cortisol, creatine kinase and subsequent relationship with pork quality	MEAT SCIENCE	2016	116		43	49
Narrative (additional literature)	Pia Brandt a,b,n, Tine Rousing a, Mette S. Herskin a, Margit Dall Aaslyng b	Identification of post-mortem indicators of welfare of finishing pigs on the day of slaughter	Livestock Science	2013	157		535	544
Narrative (additional literature)	M.L. Seshoka1,2, A.T. Kanengoni1#, F.K. Siebrits2 & K.H. Erlwanger3	The novel use of "point of care" devices to evaluate transport duration on selected pork quality parameters	South African Journal of Animal Science	2013	43	5	40	46
Narrative (additional literature)	Shu Tang1, Endong Bao1*, Karim R Sultan2, Bernhard Nowak3 and Jörg Hartung4	Transportation Stress and Expression of Heat Shock Protein Affecting Pork Quality	Pakistan Veterinary Journal	2013	34	1	112	115
Narrative (additional literature)	S Stajković, V Teodorović, M Baltić and N Karabasil	Pre-slaughter stress and pork quality	59th International Meat Industry Conference MEATCON2017	2017	85			
Narrative (additional literature)	MD Guàrdia*†, J Estany‡, J Álvarez-Rodríguez‡, X Manteca§, M Tor‡, MA Olivert†, M Gispert† and A Diestre#	A field assessment of the effect of pre-slaughter conditions and genetic stress susceptibility on blood welfare indicators in pigs	Animal Welfare	2012	21		517	526
Narrative (additional literature)	G. A. Carroll1*, L. A. Boyle2, A. Hanlon3, M. A. Palmer1, L. Collins4, K. Griffin5, D. Armstrong6 and N. E. O'Connell5	Identifying physiological measures of lifetime welfare status in pigs: exploring the usefulness of haptoglobin, C- reactive protein and hair cortisol sampled at the time of slaughter	Irish Veterinary Journal	2018	71	8	1	10
Narrative (additional literature)	L Jacobs†‡, E Delezie†, L Duchateau‡, K Goethals‡, D Vermeulen§, J Buyse§ and FAM Tuyttens*†‡	Fit for transport? Broiler chicken fitness assessment for transportation to slaughter	Animal Welfare	2017	26		335	343
Narrative (additional literature)	N.P. Caffreya,1, I.R. Dohoob, M.S. Cockrama	Factors affecting mortality risk during transportation of broiler chickens for slaughter in Atlantic Canada	Preventive Veterinary Medicine	2017	147		199	208

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	Arikan MSI, Akin ACI ,Akcay AII, Aral YI, Sariozkan SIII , Cevrimli MBI, Polat MI	Effects of Transportation Distance, Slaughter Age, and Seasonal Factors on Total Losses in Broiler Chickens	Brazilian Journal of Poultry Science	2017	19	3	421	428
Narrative (additional literature)	K. E. Kittelsen1†, R. O. Moe2, K. Hoel3, Ø. Kolbjørnsen3, O. Nafstad1 and E. G. Granquist2	Comparison of flock characteristics, journey duration and pathology between flocks with a normal and a high percentage of broilers 'dead-on-arrival' at abattoirs	Animal	2017			1	8
Narrative (additional literature)	G. Di Martino1†, K. Capello1, E. Russo1, M. Mazzucato1, P. Mulatti1, N. Ferrè1, A. Garbo1, M. Brichese2, S. Marangon1 and L. Bonfanti1	Factors associated with pre-slaughter mortality in turkeys and end of lay hens	Animal	2017			1	6
Narrative (additional literature)	Morris Villarroel 1, Fernando Pomares 2, Miguel A. Ibáñez 3, Almudena Lage 2, Paula Martínez-Guijarro 1, Jesús Méndez 2	Rearing, bird type and pre-slaughter transport conditions I. Effect on dead on arrival	Spanish Journal of Agricultural Research	2018	16	2	1	7
Narrative (additional literature)	Leonie Jacobs,∗,†,1 Evelyne Delezie,∗ Luc Duchateau,† Klara Goethals,† and Frank A. M. Tuyttens∗,†	Impact of the separate pre-slaughter stages on broiler chicken welfare	Poultry Science	2017	96		266	273
Narrative (additional literature)	Yılmaz ARAL, Mehmet Saltuk ARIKAN, Ahmet Cumhur AKIN, Çağla Yüksel KAYA KUYULULU, Seyit Can GÜLOĞLU, Engin SAKARYA	Economic losses due to live weight shrinkage and mortality during the broiler transport	Ankara Üniv Vet Fak Derg	2014	61		205	210
Narrative (additional literature)	S . Dalley ; * C . J . Baker ; * X . Yang ; * P . Kettlewell ; † R . Hoxey †	An Investigation of the Aerodynamic and Ventilation Characteristics of Poultry Transport Vehicles : Part 3 , Internal Flow Field Calculations	J . agric . Engng Res	1996	65		115	127
Narrative (additional literature)	Rafael S. SPURIO,1 Adriana L. SOARES,1 Rafael H. CARVALHO,2 Vivaldo SILVEIRA JUNIOR,3 Moisés GRESPAN,4	Improving transport container design to reduce broiler chicken PSE (pale, soft, exudative) meat in Brazil	Animal Science Journal	2016	87		277	283
Narrative (additional literature)	Guido DI MARTINO,1 Katia CAPELLO,1 Anna Lisa STEFANI,1 Luca TRIPEPI,1 Angelica GARBO,1 Marina SPERI,2 Matteo TROLESE,1 Michele BRICHESE,3 Stefano MARANGON1 and Lebana BONFANTI1	The effect of crate height on the behavior of female turkeys during commercial pre-slaughter transportation	Animal Science Journal	2017	88		1651	1657

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	Rafael H. Carvalho1 & Danielle C. B. Honorato2 & Paulo D. Guarnieri3 & Adriana L. Soares2 & Mayka R. Pedrão4 &	Assessment of turkey vehicle container microclimate on transit during summer season conditions	International Journal of Biometeorology	2018	62		961	970
Narrative (additional literature)	S. Dadgar ,* E. S. Lee ,* T. L. V. Leer ,† T. G. Crowe ,‡ H. L. Classen ,† and P. J. Shand *1	Effect of acute cold exposure, age, sex, and lairage on broiler breast meat quality	POULTRY SCIENCE	2011	90		444	457
Narrative (additional literature)	S. Dadgar ,*1 T. G. Crowe ,† H. L. Classen ,‡ J. M. Watts ,† and P. J. Shand *	Broiler chicken thigh and breast muscle responses to cold stress during simulated transport before slaughter	POULTRY SCIENCE	2012	91		1454	1464
Narrative (additional literature)	Janaina Aparecida Oliveira Silva1; Gislaine Silveira Simões2; Alessandro Rossa3; Alexandre Oba4; Elza Iouko Ida5; Massami Shimokomaki6	Preslaughter transportation and shower management on broiler chicken Dead on Arrival (DOA) incidence	Semina: Ciências Agrárias,	2011	32	2	795	800
Narrative (additional literature)	JOSÉ A. D. BARBOSA FILHO1, MARÍLIA L. V. QUEIROZ2, DANIEL DE F. BRASIL3,	TRANSPORT OF BROILERS: LOAD MICROCLIMATE DURING BRAZILIAN SUMMER	JOSÉ A. D. BARBOSA FILHO1, MARÍLIA L. V. QUEIROZ2, DANIEL DE F. BRASIL3,	2014	34	3	405	412
Narrative (additional literature)	N. B. PRESCOTT1, I! S. BERRY, S. HASLAM, and D. B. TINKER	CATCHINAGND CRATING TURKEYS EFFECTS ON CARCASS DAMAGE, HEART RATE, AND OTHER WELFARE PARAMETERS	j. Appli. Poultry Res	2000	9		424	432
Narrative (additional literature)	M.A. Mitchell1 and P.J. Kettlewell2	Transport of chicks, pullets and spent hens	In: WELFARE OF THE LAYING HEN. WPSA (UK Branch) Symposium Summer 2003	2003			1	20
Narrative (additional literature)	Mitchell, M.A., Carlisle, A.J., Hunter, R.R. & Kettlewell, P.J.	The responses of birds to transportation	In the Proceedings of the World Poultry Congress, Montreal, Canada, 22nd-24th August	2000			1	14
Narrative (additional literature)	Mitchell, M.A	Influence of pre-slaughter stress on animal welfare and processing efficiency	World's Poultry Science Journal	2006	62		254	
Narrative (additional literature)	Nilipour, A.H.	Poultry in transit are a cause for concern	World Poultry	2002	18	2	30	33

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	Mitchell, M.A	Chick transport and welfare	AVIAN BIOLOGY RESEARCH	2009	2	1	99	105
Narrative (additional literature)	Yossi Wein,∗ Zohar Geva,† Enav Bar-Shira,∗ and Aharon Friedman∗,1	Transport-related stress and its resolution in turkey pullets: activation of a pro-inflammatory response in peripheral blood leukocytes	Poultry Science	2017	96		2601	2613
Narrative (additional literature)	COUNCIL REGULATION (EC)	on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97	Official Journal of the European Union	2005				
Narrative (additional literature)	COUNCIL REGULATION (EC)	EUROPEAN CONVENTION for the Protection of Animals during International Transport (revised)	Official Journal of the European Union	2004				
Narrative (additional literature)	Department for Environment, Food and Rural Affairs (DEFRA)	Welfare of Animals During Transport: Council Regulation (EC) No 1/2005 on the protection of animals during transport and related operations. The Welfare of Animals (Transport) (England) Order 2006 and parallel national legislation in Scotland, Wales and Northern Ireland	Guidance on implementation in the United Kingdom	2011				
Narrative (additional literature)	Department for Environment, Food and Rural Affairs (DEFRA)	Animal Welfare Evidence Plan Policy portfolio: Animal Health and Welfare: Disease Control Timeframe covered by Evidence Plan: 2013/14 – 2017/18		2013				
Narrative (additional literature)	Jesús de la Fuentea,∗, Elisabeth González de Chávarria, Mónica Sánchezc, Ceferina Vieirac, Sara Lauzuricaa, Maria Teresa Díazc,d, Concepción Pérezb	The effects of journey duration and space allowance on the behavioural and biochemical measurements of stress responses in suckling lambs during transport to an abattoir	Applied Animal Behaviour Science	2012	142		30	41
Narrative (additional literature)	MW Fisher, PD Muir, NG Gregory, BC Thomson, NB Smith, PD Johnstone & N Bicknell	The effects of depriving feed to facilitate transport and slaughter in sheep – a case study of cull ewes held off pasture for different periods	New Zealand Veterinary Journal	2015	63	5	260	264
Narrative (additional literature)	Ana I. RodríguezC, Almudena CózarA,B, Luis CalvoC and Herminia VergaraA,B,D	Effect of bedding materials during transport on welfare indicators and microbiological quality in lambs	Animal Production Science	2017	57		1924	1930
Narrative (additional literature)	Grisel Navarro, Eduardo Santurtun1, Clive J.C. Phillips∗	Effects of simulated sea motion on stepping behaviour in sheep	Applied Animal Behaviour Science	2017	188		17	25

Framework	Authors	Title	Source Title	Year	Vol	Is	Start Page	End Page
Narrative (additional literature)	Eduardo Santurtun□, Clive J.C. Phillips	The effects of regularity of simulated ship motions on the behaviour and physiology of sheep	Applied Animal Behaviour Science	2018	204		43	52
Narrative (additional literature)	Clive Phillips	The welfare risks and impacts of heat stress on sheep shipped from Australia to the Middle East	The Veterinary Journal	2016	218		78	85
Narrative (additional literature)	Yu Zhang a,*, Allan T. Lisle b, Clive J.C. Phillips a	Development of an effective sampling strategy for ammonia, temperature and relative humidity measurement during sheep transport by ship	Biosystems ENGINEERING	2017	155		12	23
Narrative (additional literature)	Almudena Cozar1,2, Ana I. Rodriguez3, Paula Garijo1,2, Luis Calvo3 and Herminia Vergara1,2	Effect of space allowance during transport and fasting or nonfasting during lairage on welfare indicators in Merino lambs	Spanish Journal of Agricultural Research	2016	14	1	1	9
Narrative (additional literature)	Pullin, A and Stewart, G	Guidelines fot systematic review in conservation and evironmental management	Conservation Biology	2006	20	6	1647	1656
Narrative (additional literature)	E. Aiassa, J.P.T. Higgins, G.K. Frampton, M. Greiner, A. Afonso, B. Amzal, J. Deeks, J.-L. Dorne, J. Glanville, G. L. Lövei, K. Nienstedt, A.M. O'connor, A.S. Pullin, A. Rajić & D. Verloo	Applicability and feasibility of systematic review for performing evidence-based risk assessment in food and feed safety	Critical Reviews in Food Science and Nutrition	2015	55	7	1026	1034
Narrative (additional literature)	Eloise S. Fogartya David L.Swaina Greg Croninb Mark Trottera	Autonomous on-animal sensors in sheep research: A systematic review	Computers and Electronics in Agriculture	2018	150		245	256
Narrative (additional literature)	Compton CWR1, Heuer C2, Thomsen PT3, Carpenter TE2, Phyn CVC4, McDougall S5.	Invited review: A systematic literature review and meta-analysis of mortality and culling in dairy cattle.	J Dairy Sci	2017	100	1	1	16

APPENDIX B: A CALL FOR EVIDENCE ON CONTROLLING LIVE EXPORTS FOR SLAUGHTER AND TO IMPROVE ANIMAL WELFARE DURING TRANSPORT AFTER THE UK LEAVES THE EU.

Department
for Environment
Food & Rural Affairs

A call for evidence on controlling live exports for slaughter and to improve animal welfare during transport after the UK leaves the EU.

April 2018

This publication is available at www.gov.uk/government/publications

Any enquiries regarding this publication should be sent to us at:

The Animal Welfare Team

Area 5B

Nobel House

17 Smith Square

London SW1P 3JR

Or email: animalwelfare.consultations@defra.gsi.gov.uk

www.gov.uk/defra

Contents

Introduction

Purpose

1. The purpose of this call for evidence is to seek views on controlling live exports of farm animals for slaughter once the United Kingdom (UK) has left the European Union (EU), in order to improve animal welfare. The UK Government also wishes to consider more broadly what improvements could be made to the way animals are transported once the UK has left the EU. Following this call for evidence a consultation may be issued in relation to proposed UK Government measures, which could include regulatory measures as well as prohibitions.

2. This call for evidence is issued on behalf of the UK Government and Devolved Administrations of Wales, Scotland and Northern Ireland.

Scope

3. The current legislation which protects animals during transport and related operations is European Council Regulation (EC) No 1/2005, on the protection of animals during transport and related operations. Animal welfare is a devolved matter and this is administered and enforced through separate provisions which apply in England, Wales, Scotland and Northern Ireland.

4. The UK Government would like the welfare in transport regulatory regime to reflect fully the latest scientific and veterinary knowledge after the UK has left the EU. The UK Government wishes to improve the welfare of animals during transport by:

    a. Reviewing the standards of welfare that currently apply, taking account of the most up-to-date veterinary and scientific knowledge e.g. on stricter journey times, and;

    b. Proposing a series of improvements and reforms in due course. The UK Government will work with Devolved Administrations to try to ensure that any improvements are introduced consistently as far as possible and without disadvantaging agriculture in any part of the UK.

5. We are asking the Farm Animal Welfare Committee (FAWC) to review existing standards and their application and to make recommendations for improvements. In parallel we are seeking views and evidence via this public call for evidence on both how well the current transport regulatory regime is working, and on how it might be improved after the UK has left the EU. The outcome of this call for evidence will inform FAWC's review.

6. In addition research has been commissioned by Defra and is being undertaken by The Scotland's Rural College (SRUC) and University of Edinburgh. This research will explore the welfare issues relating to farm animals during transport through a systematic literature review. This work will feed into and provide further information for FAWC's review.

7. In launching this call for evidence the UK Government is seeking particular views on the issue of controlling the export of live animals, to help inform implementation of the Government's manifesto commitment that 'as we leave the EU we can take early steps to control the export of live farm animals for slaughter'.

8. In so doing the UK Government acknowledges calls to ban live animal exports especially for slaughter. Recently, an e-petition to Parliament to "end the export of live farm animals after Brexit" received nearly 100,000 signatures and was debated in Westminster Hall in February 2018. A recent EU-wide petition called "Stop the trucks" which received over one million signatures across Europe[66] called upon the EU Commission to allow ports to refuse the trade in live animal exports. In 2017 Theresa Villiers MP introduced a Private Members' Bill titled the Live Animal Exports (Prohibition) Bill which seeks to ban the export of live farm animals that are kept or bred for the production of food, wool or skin. In 2016 Craig MacKinlay MP introduced a Private Members' Bill which sought to give a power to local authority-owned ports to prevent animals being exported.

[66] Source: http://www.eurogroupforanimals.org/tag/stop-the-trucks

9. The UK Government would prefer animals to be slaughtered close to the point of production, and considers that a trade in meat and meat products is more desirable than the long distance transport of animals specifically for slaughter. It is important to emphasise that any future proposed UK Government reforms should be grounded and justified in terms of delivering animal welfare objectives.

10. This call for evidence considers journeys involving England, Scotland, Wales and Northern Ireland. Animal welfare is a devolved matter and we will discuss the evidence and any future proposals with the Devolved Administrations.

Audience

11. Anyone may respond to the call for evidence. Those who have an interest include:

- Animal welfare organisations.
- The veterinary profession.
- Animal welfare enforcement bodies.
- Trade bodies.
- Farm unions.
- Live animal haulage companies.
- Farmers.
- Pet couriers.
- Airlines.
- Ferry operators.
- Train haulage companies.
- Livestock/animal vehicle manufacturers.
- Animal markets.

Responding to the call for evidence

12. This call for evidence starts on 10 April 2018 and closes on 22 May 2018.

We would ask you to respond to the consultation questions using the online tool which can be found on Citizen Space at: https://consult.defra.gov.uk/animal-health-and-welfare/live-exports-and-improving-welfare-in-transport/

13. Responses could also be sent to Defra by email or post. Please state:

- **Your name.**
- **Your email address.**
- **Your organisation.**

14. Enquiries and responses should be directed to:

    E-mail: animalwelfare.consultations@defra.gsi.gov.uk

    or

    The Animal Welfare Team
    Area 5B, Nobel House
    17 Smith Square
    London SW1P 3JR

15. If you would like to receive hard copies of the call for evidence documents, you may contact the consultation hub.

After the call for evidence

16. Members of the public may ask for a copy of the responses under the Freedom of Information legislation. If you do not want your response – including your name, contact details and any other personal information – to be publicly available, please say so clearly in writing when you send your response to the call for evidence. Please note, if your computer automatically includes a confidentiality disclaimer this will not count as a confidentiality request. Please explain why you need to keep the details confidential. We will take your responses into account if someone asks for this information under the Freedom of Information legislation. However, because of the law, we cannot promise that we will always be able to keep those details confidential.

17. **Please note that the call for evidence will be open for a period of 6 weeks.** After the call for evidence a UK Government consultation may be launched relating to proposed UK Government reforms.

Call for Evidence

Background

18. Transport itself can be stressful for animals, for example as a result of loading, unloading and transportation in an unfamiliar environment. [67]

19. All forms of transport (road, rail, sea and air) may have negative effects on the animal's welfare. There is evidence to show transport can compromise animal welfare in a number of ways through, for example, extreme temperature ranges, lack of food and water, insufficient ability to rest, noise and vibration. [2]

Welfare in transport standards

20. The current legislation which protects animals during transport and related operations is European Council Regulation (EC) No 1/2005, on the protection of animals during transport and related operations (referred to hereafter as the 'EU Regulation'). This is administered and enforced through separate provisions applying in England, Wales, Scotland and Northern Ireland. Live farm animals can be transported for several purposes, including breeding, production, and slaughter. Breeding animals are generally higher value and are often transported in conditions where animal welfare is voluntarily set at a higher standard.

21. A report published in 2011 by the EU Commission found that overall the EU transport regulation had a positive effect on the animal's welfare but that serious welfare problems during transport may exist.[68] We would like the welfare in transport regulatory regime which applies after the UK has left the EU to reflect the latest knowledge of animal welfare [2] and as such give the level of protection we would wish to see.

22. In view of this we have asked FAWC to undertake a review of the requirements to protect animal welfare during transport and to make recommendations. In parallel we are seeking views and evidence via this public call for evidence, the outcome of which will inform FAWC's review. In addition research has been commissioned by Defra and is being undertaken by Scotland's Rural College (SRUC) and The University of Edinburgh. This research will feed into and provide further information for FAWC's review.

[67] EFSA Journal 2011; 9(1):1966. Scientific Opinion Concerning the Welfare of Animals during Transport
[68] EU Commission, 10 November 2011. Report From The Commission To The European Parliament And The Council On The Impact Of Council Regulation (EC) No 1/2005 On The Protection Of Animals During Transport.

Animal welfare concerns

23. This call for evidence seeks views and information on all aspects of animal welfare in transport, and on all possible reform options. The purpose is to understand and assess what UK Government reforms might be proposed in future, including in view of the manifesto commitment that 'as we leave the EU we can take early steps to control the export of live farm animals for slaughter'. Future proposed reforms in this area ought to be grounded and justified in terms of delivering animal welfare objectives.

24. A series of questions are set out below. These questions:

    - Seek factual information about the transport of live animals which you may currently undertake, in order to improve the evidence base.
    - Seek views and evidence on how well current welfare in transport requirements and standards protect animal welfare, including views on the main elements of welfare in transport.
    - Seek views on possible future reform ideas, including the justification for them in animal welfare terms.

25. We are interested in views on the possible differences applying to different animal species. In relation to farm animals we are principally interested in cattle, sheep, pigs, goats, horses and poultry.

26. We are interested in views on the possible differences applying to different modes of transport, such as transport by road, by rail, by boat and by air, and on further differences applying within each mode.

27. We are interested in views on the possible differences applying to different journey purposes and associated final destinations, such as slaughter, production and breeding.

28. We are also interested in views on how animal welfare may be affected by combinations of the above. For example if there are greater welfare concerns about a particular species using a particular mode of transport for a particular purpose.

Q1: We would welcome factual information on animals you currently transport to help us develop a better understanding of current movements.

a) What species of animal(s) do you transport? What volumes, how often and for what purpose i.e. slaughter, production or breeding?

b) When transporting animals **within** the UK, what are your average journey durations?

c) Do you buy or sell animals at market? If so, how long does it take to transport animals to or from the market? How long do animals on average spend in the market?

d) When transporting animals **within** the UK, does the journey involve road, rail, air or sea? (Please select all that apply).

e) Do you **export** animals **outside** the UK? If yes;

   i. What species do you **export** and in what volumes and how often?

   ii. Do you **export** animals for slaughter or production or breeding? (Please select all that apply).

   iii. Please indicate which country(s) you export to.

f) When transporting animals to other EU Member States, what are your average journey durations?

g) When transporting animals to other EU Member States, does the journey involve road, rail, air or sea? (Please select all that apply)

h) If transporting animals to **third countries**, what are your average journey durations?

i) If transporting animals to third countries, does the journey involve road, rail, air or sea? (Please select all that apply)

j) Do you **import** animals? If yes;

   i. What species do you **import** and in what volume and how often?

ii. Do you **import** animals for slaughter or production or breeding? (Please select all that apply).

iii. Please indicate which country you import from.

k) Are you based in Northern Ireland? If yes;

i. Do you transport animals to and from The **Republic of Ireland**?

ii. What species of animals do you transport and in what volume and how often?

iii. Do you **transport** these animals for slaughter or production or breeding? (Please select all that apply).

iv. What is the average journey duration of these movements?

v. Do you transport animals to and from **GB**?

vi. What species of animals do you transport and in what volume and how often?

vii. Do you **transport** these animals for slaughter or production or breeding? (Please select all that apply).

viii. What is the average journey duration of these movements?

Q2: We would welcome your views on how well current welfare in transport requirements and standards are currently working.

a) What are the key current regulatory requirements that you think protect the welfare needs of animals during transport?

b) What issues or deficiencies in the current regulations are you aware of?

c) What do you consider are the most important considerations for improving animal welfare during the transport of animals or related operations? Please indicate if your priority areas are species specific.

d) The current EU regulation requires transporters to reach a higher standard if they are transporting animals on long journeys i.e. more than 8 hours. How do you think we should define long journeys?

e) What evidence do you have that journey length influences the welfare conditions for animals?

f) On long journeys, the regulation currently requires rest stops to allow the animals to recover before continuing their journey. There is no limit on the number of rest stops required nor a maximum journey limit.

   i. Do you believe there should be a maximum number of rest stops? Please indicate which species you are referring to.

   ii. Do you believe that there should be a maximum journey limit? Please indicate which species you are referring to.

g) What evidence do you have on how the different forms of transport (road, rail, sea, air) affect animal welfare? Please indicate which species you are referring to.

h) Do you have any evidence on the transport of unweaned animals? What age related conditions do you think should apply? Please indicate which species you are referring to.

i) What conditions do you think should apply to animals post transport? Please indicate which species you are referring to.

j) How do you think “fitness to travel” should be defined? Please provide an explanation for your answer. Please indicate which species you are referring to.

Q3: We would welcome your views on possible future reform ideas.

a) Does the journey end point i.e. slaughterhouse or production facility influence animal welfare? Please provide an explanation for your answer.

b) Do you think that a ban on live animal exports, or imports, should apply? If so, for what purpose i.e. slaughter, production. Please give reasons for your response.

c) Currently, under the Regulation, livestock vessels (which keep animals in pens) and lorries require specific pre-approval inspections, whereas roll-on, roll-off vessels or aircrafts do not. Do you think that all transporters should be inspected and approved? If so, why?

d) What other factors should be considered and addressed to improve the welfare of animals during transport?

e) Do you have any other proposed UK Government policy reforms?

Annex A: Volume of animal imports and exports

1. Live animals can be transported for several purposes, including breeding, production and slaughter.

2. The trade in animal exports and imports are monitored by Trade Control and Expert System (TRACES) which records the number of animals exported and imported from around the EU.

3. Today, the number of animals exported from the UK to EU Member States is provided in **Table 1.**[69] This shows the volume of trade in live exports for slaughter, production and breeding to the EU during 2016. This indicates the scale of the trade for the whole of the UK.

Table 1: The volume of trade in live exports for slaughter, fattening and production and breeding to the EU in 2016.

Purpose	Livestock species				
	Sheep	Cattle	Pigs	Poultry	Horses
Slaughter	385,099	10,464	8,916	n/a	0
Production	93,778	25,433	2	13,291,141	n/a
Breeding	4,978	6,453	1,695	3,689,957	468
Other	4	6	2	n/a	16,461
Total	**483,859**	**42,356**	**10,615**	**16,981,098**	**16,929**

a) Other: not known the purpose of export.

4. The number of animals imported from the EU Member States to the UK is provided in **Table 2.**[70] This shows the volume of trade in live imports for slaughter, production and breeding from the EU during 2016. This indicates the scale of the trade for the whole for the whole of the UK.

Table 2: The volume of trade in live imports for slaughter, fattening and production and breeding from the EU in 2016.

[69] Source: published data from TRACES, available at https://ec.europa.eu/food/animals/traces/facts-figures_en 2016 report: https://ec.europa.eu/food/animals/traces/facts-figures_en
[70] Source: published data from TRACES, available at https://ec.europa.eu/food/animals/traces/facts-figures_en 2016 report: https://ec.europa.eu/food/animals/traces/facts-figures_en

Purpose	Livestock species				
	Sheep	Cattle	Pigs	Poultry	Horses
Slaughter	552	8,664	356,746	n/a	0
Production	1,749	10,367	99,192	n/a	n/a
Breeding	813	25,718	3,949	16,102,421	180
Other	0	9	0	3,878,975	7,644
Total	**3,114**	**44,758**	**459,887**	**19,981,396**	**7,824**

a) Other: not known the purpose of import.

<u>APPENDIX C:</u> TEMPERATURE RANGE GUIDES FOR CATTLE, SHEEP, PIGS AND POULTRY.

Note: the temperature ranges below should only be used as a guideline. These are based on expert opinion, but will require further scientific research to validate these temperature ranges.

<u>Cattle</u>

The temperature range over which and animals remains physiologically and psychologically unstressed is heavily influenced by factors including the quality of the journey, environmental considerations (air speed, moisture/humidity) and that of the animal itself (coat length and wetting, previous adaptation, diet/metabolism). Under normal environmental and animal conditions, special consideration should be given as to how to maintain the thermal comfort of cattle when environmental temperatures fall outside of the range given in **Table C.1**.

Table C.1: A guide to determine the temperature ranges of cattle.

		Temperature range	
		Lower	Upper
Calves	<3 weeks	15°C	25°C
Calves & young stock	>3 weeks	10°C	25°C
Adult cattle	Summer coat	10°C	22°C
Adult cattle	Winter coat	0°C	22°C

Poultry
Poultry are mostly transported in containers, for this reason the internal temperature range should be 22-28 ºC for end of lay birds and broilers. This temperature range is similar to the temperature ranges that UK hatcheries operate under.

Pigs
Weaned pigs are particularly susceptible to the cold, so, deep straw should be provided for weaned pigs if temperatures are below 25ºC and for journeys longer for 1 hour. Finishers and sows are prone to overheating. To prevent overheating, a constant air temperature should be maintained if the air temperature is above 15ºC. Under extreme heat (above 25ºC), finishers/ sows should not be transported to help reduce overheating.

Sheep
FAWC recommends that APHA guidance should be followed for shorn sheep [71] during colder months. APHA recognise that cold temperatures during transport can compromise animal welfare and to transporters must consider the cold temperatures when planning their journey.

All other animals
FAWC recommends that no animal should not be transported under extreme outside temperatures, as these external temperatures would influence the internal environment within the transporter, which may lead to animal welfare issues. As there are a number of factors that influence the internal environment inside the transporter then these guides should be used until further scientific evidence is available to provide species-specific temperature guides. Therefore, no animal should be transported in temperatures above 35ºC unless the vehicle can regulate the temperature range.

APPENDIX D: ORGANISATIONS THAT GAVE EVIDENCE AND ASSISTANCE

National Farmers Union
British Meat Processors Association
British poultry council
World Horse Welfare
British Horseracing Authority
Thoroughbred Breeders' Association
British Equestrian Federation
Livestock Meat Commissioner NI

[71] Newly shorn sheep should only be presented for any journey, including export journeys, during the period from 1 November to 31 March:
•if they have a staple growth of at least 7.0mm (this may be achieved either by allowing re-growth or by shearing with a suitable long comb) and
•if the sheep have not been shorn within 24 hours prior to departure.

Ulster Farmers Union
The Dogs Trust
RSPCA
The British Veterinary Association
Eyes on Animals
World Animal Protection
Compassion in World Farming
Laboratory Animals Science Association
Ornamental Aquatic trade association
Livestock Auctioneers Association
National Pig Association
National Sheep Association
Road Haulage Association
Game Farmers Association
National Farmers Union Scotland
Orkney Auction Mart
Aberdeen and Northern Marts
Shetland Livestock Marketing Group
Scottish Beef Association
Scottish Association of Meat Wholesalers
National Sheep Association Scotland
Road Haulage Association Scotland
British Horse Society Scotland
British Veterinary Association Scotland
Scotbeef
Northlink Ferries
Ramsgate Port
Dover Port
Monmouthshire Livestock Centre
Dolidre Farm

FAWC would like to thank all the individuals who have given evidence.

The systematic review was conducted by Prof Malcolm Mitchell, Peter Kettlewell and Prof Cathy Dwyer from Scotland’s Rural University College and Dr Jess Martin from the University of Edinburgh.

APPENDIX E: MEMBERSHIP OF THE FARM ANIMAL WELFARE COMMITTEE

Peter Jinman OBE* - Chair
Martin Barker
Dr Andy Butterworth*
Richard Cooper*
Dr Jane Downes
Dr Troy Gibson
Dr David Grumett
Dr Maria Carmen Hubbard
Richard Jennison*
Richard Kempsey*
Dr Dorothy McKeegan
Professor Richard Moody
Debbie Stanton*
Mark White*
*Working members of the transport sub-group.

Dr Christopher Browne - FAWC transport secretariat

APPENDIX F: GLOSSARY OF TERMS

APHA - Animal and Plant Health Agency
CfE – Call for Evidence
CoC – Certificate of Competence
DA - Devolved Administrations
Defra – Department for Environment, Food and Rural Affairs
EFSA - European Food Safety Authority
EU – European Union
FAWC – Farm Animal Welfare Committee
HGV - Heavy goods vehicle
LA - Local Authority
NI – Northern Ireland
RoI – Republic of Ireland
SRUC - Scotland's Rural University College
TRACES - Trade Control and Expert System
UK - United Kingdom
UoE - University of Edinburgh
WATEO - The Welfare of Animals (Transport) (England) Order 2006

APPENDIX G: CONTACT DETAILS

Farm Animal Welfare Committee
Area 2D
9 Millbank
c/o Nobel House
17 Smith Square
London, SW1P 3JR

Tel. 0207 238 5016
Fax. 0207 238 3169

Website: https://www.gov.uk/government/groups/farm-animal-welfare-committee-fawc
E-mail: fawcsecretariat@defra.gsi.gov.uk

This publication is available at www.gov.uk/government/collections/fawc-advice-to-government
Any enquiries regarding this publication should be sent to us at fawcsecretariat@defra.gsi.gov.uk