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Welfare of pigs during transport

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Abstract

In the framework of its Farm to Fork Strategy, the Commission is undertaking a comprehensive evaluation of the animal welfare legislation. The present Opinion deals with protection of pigs during transport. The welfare of pigs during transport by road is the main focus, but other means of transport are also covered. Current practices related to transport of pigs during the different stages (preparation, loading/unloading, transit and journey breaks) are described. Overall, 10 welfare consequences were identified as highly relevant for the welfare of pigs during transport based on the severity, duration and frequency of occurrence: group stress, handling stress, heat stress, injuries, motion stress, prolonged hunger, prolonged thirst, restriction of movement, resting problems and sensory overstimulation. These welfare consequences and their animal-based measures are described. A variety of hazards were identified, mainly relating to factors such as mixing of unfamiliar pigs, inappropriate handling methods and devices, the use of pick-up pens, inexperienced/untrained handlers, structural deficiencies of vehicles and facilities, poor driving conditions, unfavourable microclimatic and environmental conditions and poor husbandry practices leading to these welfare consequences. The Opinion contains general and specific conclusions relating to the different stages of transport of pigs. Recommendations to prevent hazards and to correct or mitigate welfare consequences are made. Recommendations were also developed to define quantitative thresholds for microclimatic conditions and minimum space allowance within means of transport. The development of the welfare consequences over time was assessed in relation to maximum journey duration. The Opinion covers specific animal transport scenarios identified by the European Commission relating to transport of cull sows and 'special health status animals', and lists welfare concerns associated with these.

Keywords: pig, sow, animal welfare assessment, Farm to Fork Strategy, welfare consequences, animal-based measures, hazards, quantitative thresholds

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Waiver: In accordance with Article 21 of the Decision of the Executive Director on Competing Interest Management a waiver was granted to Sandra Edwards, Genaro C Miranda de La Lama and Luigi Faucitano, experts of the Working Group WG/P/AHAW/2020/05 -AHAW Welfare Farm to Fork. Pursuant to Article 21(6) of the aforementioned decision, the concerned experts were allowed to take part in the drafting and in the discussion of the scientific output but were not allowed to take up the role of, or act as, chairman, vice-chairman or rapporteur of the Working Group. Any competing interests are recorded in the respective minutes of the meetings of the Working Group WG/P/AHAW/2020/05 - AHAW Welfare Farm to Fork.

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Summary

In the framework of its Farm to Fork Strategy, the Commission is undertaking a comprehensive evaluation of the animal welfare legislation, including Council Regulation (EC) No 1/2005[1]. The current EU legislation on the protection of animals during transport is based on a Scientific Opinion adopted in 2002. Against this background, the European Commission requested the European Food Safety Authority (EFSA) to give an independent view on the protection of animals during transport for different groups and categories of farmed animals. It also requested EFSA to propose detailed measures to prevent hazards and mitigate the welfare consequences for seven specific scenarios. This Opinion deals with the protection of pigs during transport.

The scientific assessment was carried out by breaking down the transport of pigs into four distinct stages, namely preparation, loading/unloading, transit and journey breaks. For road transport, which is the most common transport practice, each stage was described in terms of current practice and assessed in terms of welfare consequences, animal-based measures (ABMs), and hazards leading to the welfare consequences. In addition, recommendations to prevent hazards and to correct or mitigate welfare consequences were developed. Recommendations were also developed in relation to quantitative thresholds for microclimatic conditions and for spatial thresholds (minimal space allowance) within the means of transport. In addition, the development of welfare consequences over time were assessed in relation to maximum journey duration.

While the Opinion focuses primarily on the road transport of pigs, there are specific sections dealing with air and rail transport. Welfare concerns (defined as an area or a topic to which special attention should be given in order to potentially avoid welfare consequences) related to the transport of cull sows and 'special health status animals' are covered in a separate section of the Opinion.

According to TRACES, an average of ~ 31 million pigs were transported between Member States per year in the period from 2019 to 2021, across all means of transport. This means that pigs are the species, among animals transported as free-moving, that are transported in the highest numbers in the EU by far. Road transport constituted 99% of total pig transport reported in this period.

In total, ten welfare consequences were identified as being highly relevant for the welfare of pigs during transport based on the severity, duration and frequency of occurrence. These were (i) group stress, (ii) handling stress, (iii) heat stress, (iv) injuries, (v) motion stress, (vi) prolonged hunger, (vii) prolonged thirst, (viii) resting problems, (ix) restriction of movement, and (x) sensory overstimulation. The occurrence of each type of welfare consequence varied depending on the stage and means of transport. Pigs may experience one or more negative affective states associated with these welfare consequences, including fear, pain, discomfort, frustration, fatigue and distress. Specific ABMs were identified for each of the highly relevant welfare consequences, including behavioural, clinical and physiological ABMs. A definition and interpretation for each ABM is provided in the Opinion. Some ABMs are relevant to more than one welfare consequence.

A wide variety of hazards were identified for the different welfare consequences and transport stages. These were related to factors such as mixing unfamiliar pigs, inappropriate handling methods and devices, the use of pick-up pens, inexperienced/untrained handlers, structural deficiencies of vehicles and facilities, poor driving and road conditions, unfavourable microclimatic and environmental conditions and poor husbandry practices.

Throughout the scientific literature, it is agreed that ensuring that animals are fit for transport before departure is of utmost importance. However, currently no agreed scientific definition of the concept of fitness for transport exists. In order to avoid doubt and misclassification of animals in relation to fitness for transport, the concept should be properly defined, professional groups (including farmers, stockpersons, drivers, haulers, inspectors and veterinarians) should be well-educated and trained, and questions on responsibility between the groups should be clarified. Also, there are only very few conditions leading animals to be unfit for transport, for which ABMs have been established and validated, including the establishment of thresholds. The main conditions rendering pigs unfit for transport, and methods for assessing fitness for transport, are provided in the Opinion. Guidelines based on ABMs for conditions leading to animals being unfit, including thresholds, should be established and validated.

Periods of pre-transport fasting should be adjusted to the category of pigs and be appropriate for the planned journey duration, and in addition take into consideration whether pigs are transported for slaughter or for further fattening/breeding. Until evidence-based thresholds are established, it is

[1] Regulation (EC) No 1/2005 of the European Council of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/9.

recommended to expose finishers being transported to a pre-transit fasting of less than 10 h. The time taken to load should be included within this 10 h period. For other pig categories pre-transit fasting should likely be shorter.

The highly relevant welfare consequences during loading/unloading of pigs are: handling stress, heat stress, and sensory overstimulation. Across the highly relevant welfare consequences, the major hazards are inappropriate handling, unsuitable facilities and high temperatures. A delay in loading and/or unloading is a hazard for a deterioration of these welfare consequences. The main preventive measures are establishment and maintenance of proper facilities, avoiding loading during hot hours and education and training of handlers.

During the transit stage, pigs will be exposed to a number of hazards, either on their own or in combination, leading to welfare consequences.

As regards microclimatic conditions during road transport of pigs, the upper threshold of the thermal comfort zone and the upper critical temperature of sows were estimated to be 20°C and 22°C dry temperature, respectively. The comparable figures were 22°C and 25°C for finishing pigs, and 25°C and 30°C for weaners of ~ 30 kg. Thus, between pig categories the sensitivity to heat stress differs. In vehicles transporting pigs, the temperature near the pigs should not exceed the upper critical temperature.

In relation to the horizontal space allowance for pigs during road transport, the available evidence suggests that a k-value of at least 0.027 in the allometric equation relating space to liveweight, is required for all categories of pigs (this equates to 0.62 m^2 for a 110-kg finishing pig).

The vertical space in a means of transport is also important for the welfare of pigs. Low vertical space is associated with reduced ventilation, lack of ability to move around and lack of space for natural movements. A proper deck height should allow the prevention of these, in order to avoid welfare consequences such as heat stress and restriction of movement. Research is needed to establish evidence-based thresholds.

The amount of time the animals are exposed to the hazards is dependent on the journey duration. The number and the severity of hazards that animals are exposed to during transport influence the resultant welfare consequences (continuous or semi-continuous, progressive and sporadic). On the basis of evidence on continuous welfare consequences involving stress and negative affective states, for the benefit of animal welfare, the journey duration and frequency, should be kept to a minimum.

To limit the impact of transport on animal welfare, in an effort to reduce the exposure to hazards and related welfare consequences, it is recommended to consider that: motion stress and sensory overstimulation starts as soon as a vehicle starts moving, and continues while the vehicle is moving, potentially leading to fatigue and negative affective states, such as fear and distress; Group stress and resultant injuries (skin lesions) are the result of post-mixing fighting and may start as soon as pigs are mixed and continues during the journey with the severity increasing potentially leading to fatigue; pain and/or discomfort from health conditions or injuries might be relatively rare, but for the affected animals the consequences might be severe, and will worsen over time during transport and may lead to suffering; resting problems severity is expected to increase with increasing duration, as the lack of resting becomes more problematic for the animals and may lead to fatigue; even when a transport vehicle is fitted with water drinkers prolonged thirst may lead to dehydration and associated negative affective states, and physiological and behavioural changes that are likely to be associated with thirst have been identified after 8 h of transport; and due to practical difficulties in feeding animals on a transport vehicle, based on behavioural and physiological indicators, prolonged hunger is likely present after 12 h of feed deprivation. Depending on the pre-transport fasting this may correspond with the early hours of a journey.

Per definition, breaks in journeys function to remove the animals from the hazards that they are exposed to during transit, and to allow them to recover from the associated welfare consequences. The available evidence suggests that, with the transport conditions currently practiced, the provision of water on the vehicle while in motion may be ineffective, in that some animals will not, or are not able to drink. Insufficient research is available to assess the effectiveness and optimal manner in which to provide water on a vehicle. No studies have documented successful feeding of pigs during the transit stage. Thus, if pigs are to recover from the welfare consequences experienced during transit they need to be unloaded from the vehicle.

A journey break at a control post allows animals to have access to resting, watering and feeding areas. However, at control posts, along with the mitigation of welfare consequences, there is also potential for exposure to hazards resulting in welfare consequences or interfering with the intended mitigation of other welfare consequences. In addition, control posts involve biosecurity risks as animals can be exposed to infectious diseases through direct or indirect contact with other animals and opportunistic pathogens. Across the categories of pigs typically transported on journeys involving journey breaks, the scientific focus on control posts has been limited. This means that whether control posts in their current state fulfil their intended function is not known.

The specific scenarios relevant to pigs that EFSA was asked by the Commission to consider were the transport of cull sows to slaughterhouses, and issues relating to 'special health status animals', i.e. animals whose unloading before the final destination might jeopardise their health status.

Health issues are major causes for culling sows, so these animals present additional challenges when it comes to transporting them to a slaughterhouse. Therefore, the key animal welfare issue for cull sows transported to slaughter is to determine the fitness of the sows to be transported. In addition, heat stress is a particular concern, especially in lactating sows, because of their high sensitivity to heat. Another concern during transport is that sows are often mixed with unfamiliar individuals, leading to group stress and resultant injuries. The Opinion contains a number of recommendations on how welfare consequences from transport can be prevented or mitigated for cull sows during transport to slaughter.

The failure to unload pigs in order to protect their 'special health status' presents a concern with respect to the welfare of the animals in question. If, for biosecurity reasons, pigs are not unloaded to provide required rest, feed and water, facilities must be available on the vehicle to provide the necessary resting, feeding and drinking, and suitable microclimatic conditions. However, no scientific studies have been found that confirm that this is currently possible.

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

In the framework of its Farm to Fork strategy, the Commission will start a comprehensive evaluation of the animal welfare legislation. This will include the following acts:

- Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes.
- Council Directive 1999/74/EC of 19 July 1999 laying down minimum standards for the protection of laying hens.
- Council Directive 2008/119/EC of 18 December 2008 laying down minimum standards for the protection of calves.
- Council Directive 2008/120/EC of 18 December 2008 laying down minimum standards for the protection of pigs.
- Council Directive 2007/43/EC of 28 June 2007 laying down minimum rules for the protection of chickens kept for meat production.
- Council Regulation (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/976.
- Council Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of killing.

These acts are based on scientific opinions that are outdated. The current EU legislation on the protection of animals during transport is based on a scientific opinion adopted in 2002. Since then, the EFSA adopted opinions in 2004 (two opinions) and 2011.

In the context of possible drafting of legislative proposals, the Commission needs new opinions that reflect the most recent scientific knowledge.

Against this background, the Commission would like to request the EFSA to review the available scientific publications and possibly other sources to provide a sound scientific basis for future legislative proposals.

This request is about the protection of terrestrial animals during transport.

1.1.2. Terms of Reference

The Commission therefore considers opportune to request EFSA to give an independent view on the protection of animals during transport for the following groups and categories of farmed animals:

Free-moving animals (group 1):

1) Equids (horses, donkeys and their crossings),
2) Bovine animals (cattle and calves),
3) Small ruminants (sheep and goats),
4) Pigs,

Animals in containers (group 2):

5) Domestic birds (chickens for meat, laying hens, turkeys, ducks, geese, quails, etc.)
6) Rabbits.

The request refers to any journey, i.e., journeys of less than 8 h ("short journeys"), journeys of more than 8 h ("long journeys") and long journeys that need unloading and/or feeding ("very long journeys").

1.1.2.1. Assessment of common transport practices

For each category of animals (1–6), the EFSA will describe, based on existing literature and reports, the current practices regarding:

a) the preparation for transport (including catching and crating of poultry and rabbits), loading, unloading and handling of animals at all stages of the journey, including at destination,

b) the means of transport by road, roll-on-roll-off vessels, livestock vessels, the means of transport by rail and by air,
c) the conditions within the means of transport: space, microclimatic conditions, watering and feeding,
d) the journey duration and its circumstances as well as the resting of animals in the vehicle being stationary or being unloaded,
e) the conditions for areas where animals are unloaded and/or grouped as part of the journey (assembly centres, livestock markets, control posts, EU ports).

Additionally, for each of the above practices, the EFSA will:

- Describe the relevant welfare consequences for each category of animals during each step of the process. Relevance will not need to be based on a comprehensive risk assessment, but on EFSA's expert opinion regarding the severity, duration and occurrence of each welfare consequence,
- Define qualitative or quantitative measures to assess the welfare consequences during transport (animal based measures),
- Identify the hazards leading to these welfare consequences,
- Provide recommendations to prevent, mitigate or correct the welfare consequences (resource and management based measures).

1.1.2.2. Assessment of seven specific transport practices

For the following scenarios, the Commission has identified practical difficulties or insufficient information in ensuring the welfare of animals. At least for them, the EFSA is asked to propose detailed animal-based measures and preventive and corrective measures with, where possible, either qualitative (yes/no question) or quantitative (minimum/maximum) criteria (i.e., requirements to prevent and/or mitigate the welfare consequences):

1) "Export by livestock vessels" - Transport of adult cattle, weaned calves and sheep over long journeys involving the combination road/livestock vessels;
2) "Export by road" - Transport of adult cattle, weaned calves and sheep over long journeys by road involving the use of facilities where animals are unloaded and reloaded (control posts, livestock markets) or when animals are kept in stationary vehicles for hours (exit points) including in third countries;
3) "Roll-on-roll off" - Transport of adult cattle, calves and sheep over long journeys involving the combination road/roll-on-roll-off vessels;
4) "End-of-career animals" - Transport of end of career animals to slaughterhouses of dairy cows, breeding sows, and laying hens;
5) "Unweaned calves" - Transport of unweaned calves over long journeys; this scenario will particularly consider the risks regarding fitness for transport, watering, feeding and thermal comfort under Section c of the current practices associated with inappropriate drinkers and liquid feed for unweaned calves;
6) "Horses" - Transport of horses on long journeys to slaughterhouses;
7) "Special health status animals" - Transport of ruminants and pigs where unloading them before the final destination might jeopardize their health status.

For all scenarios, the EFSA will consider the risks regarding microclimatic conditions under Section c of the current practices associated with extremely high or low temperatures including the difficulty of measuring of temperature, humidity and gas concentration within animals' compartment.

1.2. Interpretation of the Terms of Reference

This Scientific Opinion concerns the protection of pigs during transport. The fundamental premise of the work underlying this Scientific Opinion is that it is an accepted practice that humans breed animals for food, sports and leisure. The assessment does not go into details with breed differences or the consequences of the housing system or production system, from which the animals to be transported are coming, even though it cannot be excluded that welfare consequences (WCs) of transport to some extent differ depending on for example the previous husbandry conditions.

The Opinion deals with the preparation, loading and unloading, transit and journey breaks. For the purpose of this Opinion, the preparation phase involves all types of actions and animal management that take place during the interval from the decision to transport pigs until the initiation of loading of the animals onto a vehicle or other means of transport. In effect, in this Opinion, the preparation of pigs for transport essentially involves the gathering of the animals to holding facilities and the keeping of them there prior to transport. Loading starts when the first animal is moved from the holding pen into the means of transport and ends when the last animal is loaded and up until the ramp is closing. Unloading starts when the ramp is open, and the first animal exits the means of transport, and ends when the last animal exits. Loading and unloading will be dealt with together due to the similarities of the processes. The transit starts when the ramp has been closed and ends when the first animal unloads. Journey breaks conceptually apply to periods when the vehicle is stopped on the side of a road, or when animals are offloaded to other facilities for feeding, watering and resting, including control posts (CPs). Legislation regarding drivers of animal transport vehicles affect animal transport, especially on journeys with only one driver, as drivers have to have rest breaks, where vehicles will be stationary (Table 1). As these breaks are not aimed to rest, feed and water the animals, for the purpose of the current assessment, they are not included in the 'journey break' stage.

Table 1: A summary of the EU drivers' hours rules and sector specific working time rules (Department for transport, 2014)

Drivers' hours rules Regulation (EC) 561/2006	Working time rules Directive 2002/15/EC
Driving • 9 h daily driving limit (can be increased to 10 h twice a week) • Max 56 h weekly driving limit • Max 90 h fortnight driving limit	**Working time (including driving)** • Working time must not exceed average of 48 h a week (no opt out)[1] • Max working time of 60 h in one week (provided average not exceeded) • Max working time of 10 h if night work performed.[2]
Breaks • 45 min break after 4.5 h driving • A break can be split into two periods, the first being at least 15 min and the second at least 30 min (which must be completed after 4.5 h driving)	**Breaks[3]** • A driver cannot work for more than 6 h without a break. A break should be at least 15 min long. • 30 min break if working between 6 and 9 h in total.[4] • 45 min break if working more than 9 h in total.
Rest • 11 h regular daily rest[5]; which can be reduced to 9 h no more than three times a week. • 45 h weekly rest, which can be reduced to 24 h, provided at least one full rest is taken in any fortnight. There should be no more than six consecutive 24 h periods between weekly rests.	**Rest** • Same rest requirements as EU' drivers.

(1): Normally calculated over a rolling 17-week period, but can be extended to 26 weeks under a collective or workforce agreement.
(2): Can be extended under a collective or workforce agreement.
(3): EC Regulation 561/2006 is directly effective and takes precedence over EC Directive 2002/15 - Article 2.4 Directive 2002/15. Therefore, EU drivers' hours break requirements take precedence when driving.
(4): After working for 6 h a mobile worker must take a break of at least 15 min. However, if working more than 6 and up to 9 h in a shift a mobile worker needs to take a break totalling at least 30 min - this could be two breaks of 15 min. Where a shift will contain more than 9 h of working time, a total of 45 min of break is needed.
(5): Alternatively, this regular daily rest period may be taken in two periods, the first of which must be an uninterrupted period of at least 3 h and the second an uninterrupted period of at least 9 h.

This Opinion does not focus on the different types of premises defined in the transport Regulation (e.g. markets, assembly centres) but refers to them where appropriate. Destination is not covered, but only specified when important considerations are found. In case of animals arriving for slaughter, additional information can be found in the EFSA Opinion on Welfare of Pigs at Slaughter (EFSA AHAW Panel, 2020).

Within pigs, different animal categories exist, such as gilts and weaners. Across this Scientific Opinion, focus is given to three often transported categories of pigs: weaners transported for further fattening, finishers transported to slaughter, and cull sows and boars. When specific studies are referred to, the average body weights of the animals involved are mentioned (when available) as well as the animal category involved in the study (e.g. gilts).

The scientific assessment carried out by EFSA takes two forms. First, for road transport practices, which is the most common transport practice, the transport stages are described and assessed in terms of WCs, animal-based measures (ABMs) and hazards leading to the WCs. In addition, recommendations to prevent hazards, and mitigate/correct WC are provided. The preventive measures (PRE) relate to the hazards, and the corrective/mitigative measures refer to the WCs. Where possible, the assessment leads to the establishment of recommendations on quantitative thresholds for microclimatic conditions within means of transport (maximum temperature), and to spatial thresholds (minimum space allowance). In addition, the development of WCs over time is assessed in relation to maximum journey duration.

Second, for the specific industry practices (specific scenarios) listed in the mandate that relate to pigs, EFSA examines selected welfare concerns (defined as an area or a topic to which special attention should be given in order to potentially avoid WCs), and, where possible, suggests recommendations. A similar approach will be taken for transport by air and rail. In relation to the specific transport practice of 'end-of-career animals' in this Scientific Opinion, this animal category will be denoted 'cull animals', which is the term used in scientific literature.

A list of WCs is selected among those reported in the guidance protocol published by EFSA (EFSA AHAW Panel, 2022a). These WCs can lead to negative affective states such as fear, pain and/or distress. For each transport stage, the highly relevant WCs are selected based on literature and expert opinion considering the severity, duration and frequency of occurrence of the WC. When possible, each WC is linked to one or more ABMs that are indicative of it.

During preparation for transport, animals might present health conditions (including WCs, such as injuries) that may increase in severity during transport. Certain physiological conditions, while not being a WC as such (e.g. pregnancy or certain age categories), are conditions that predispose the animal to experience WCs if transported. Rather than assessing all WCs that might occur at any given stage of transport due to animals being unfit for transport, a separate section in the Scientific Opinion, focusing on fitness for transport is developed as part of the assessment of the preparation stage.

For the purposes of this scientific assessment, failure to implement or non-compliance with the current rules as specified in the transport regulation are not considered. This is outside the remit of EFSA as a risk assessor. During the work, the EFSA Experts may include scientific information from practices currently prohibited in the EU.

The assessment is not split according to the current legislation, for example specifying that 8 h as journey duration is the threshold between short and long journeys (each with specific legislative requirements). Alternatively, the assessment is performed on a journey carried out in the EU of an unspecified length and duration.

2. Data and methodologies

2.1. Data

2.1.1. Data from literature

The information contained in the scientific papers and reports identified as relevant during the literature search was used as a basis for the text of this Scientific Opinion. Additional sources were added by the WG experts when dealing with specific sections.

2.1.2. Data from Public Consultation

To consult interested parties and gain feedback on EFSAs interpretation of the transport mandate, a Public Consultation was launched in the period 15 April–10 June 2021. In particular, EFSA called on interested parties to:

- identify current transport practices of particular concern not already identified by EFSA in the interpretation of mandate;
- describe the practical difficulties or insufficient information in ensuring the welfare of animals, for the specific transport practices listed in the request from the European Commission and for any other additional practices of concern that might be identified;

- provide any available recorded data from road or sea transport, for example from a data logger, related to the microclimatic environment (temperature, humidity and ammonia levels). The data should demonstrate a link between the microclimatic conditions and any adverse WCs that are experienced by the animals during transport.

The information received in the Public Consultation were considered by the EFSA experts as part of their work on this Opinion (See Annex A: Report of the Public Consultation on the Protection of Animals during Transport, published under 'Supporting Information' in the Opinion on transport of small ruminants).

2.2. Methodologies

This Scientific Opinion follows the guidance protocol that was developed by the AHAW Panel to deal with all the mandates in the context of the Farm to Fork strategy revision (EFSA AHAW Panel, 2022a).

To address the terms of reference of the mandate, EFSA translated the assessment questions into more specific sub-questions. These are interrelated, meaning that the outcome of each sub-question is necessary to proceed to the next sub-question. The approach to develop the sub-questions was based on evidence from the scientific literature and expert opinion. The translation of the assessment questions into sub-questions is mapped in Table 2.

Table 2: Specific assessment questions and sub-questions of the mandate

Assessment Questions		**Sub-questions**	
i.	**Describe the current transport practices**	***1.*** *Identify and select relevant transport scenarios (common animal transport practices per species and animal category)*	***2.*** *Describe the transport practices*
		Aim: Animal transport practices to be considered in the assessment are identified and selected to be common (representative of the current practice) in the EU. Approach: expert opinion via group discussion. Relationship with assessment question: This sub-question is necessary for the overall assessment question requiring the description of the practices.	Aim: All the animal transport practices per animal category identified and selected from Sub-question 1 are described narratively Approach: Literature review. Relationship with assessment question: this corresponds to the assessment question and is necessary for the next assessment question.
ii.	**Describe the relevant welfare consequences that may occur due to the practices**	***3.*** *Identify the welfare consequences common for all mandates and provide their definitions*	***4.*** *Select the most relevant welfare consequences for the selected animal transport practices*
		Aim: to identify the welfare consequences and provide a definition for them. EFSA generates a list of welfare consequences common for all mandates. Approach: Expert opinion via group discussion (see focus and full resulting list in Section 3.2). Relationship with assessment question: the list of all possible welfare consequences is necessary for the next assessment question asking to identify the most relevant ones per each system	Aim: To select the most relevant welfare consequences for each of the previously defined animal transport scenarios per species or animal category. Approach: expert opinion via EKE (see Section 2.2.1). Relationship with assessment question: this corresponds to the assessment question, is related to Sub-question 1 in which relevant welfare consequences are identified only for current transport scenarios.
iii.	**Define qualitative or quantitative animal-based measures (ABMs) to assess these welfare consequences**	***5.*** *Identify the feasible ABMs for the assessment of the most relevant welfare consequences*	***6.*** *Describe the feasible ABMs for the assessment of the most relevant welfare consequences*
		Aim: The ABMs for the assessment of the welfare consequences previously identified as relevant are selected (only for feasible ABMs). Approach: Expert opinion via group discussion. Relationship with assessment question: This corresponds to the assessment question and is related to Sub-question 4 in which ABMs are identified only for the most relevant welfare consequences	Aim: The ABMs for the assessment of the welfare consequences previously identified as the most relevant are described. Approach: Literature review. Relationship with assessment question: related to Sub-question 5.

Assessment Questions		Sub-questions	
iv.	**Identify the hazards leading to these welfare consequences**	***7.*** *Identify the hazards leading to the most relevant welfare consequences*	***8.*** *Describe the hazards leading to the most relevant welfare consequences*
		Aim: The hazards leading to the most relevant welfare consequences are identified. Approach: Expert opinion via group discussion. Relationship with assessment question: This corresponds to the assessment question and is related to Sub-question 4 in which hazards are identified only for the most relevant welfare consequences	Aim: The hazards are described. Approach: Literature review. Relationship with assessment question: related to Sub-question 6.
v.	**Provide recommendations to prevent, mitigate or correct the hazards**	***9.*** *Identify the preventive and corrective measures for the most relevant welfare consequences*	***10.*** *Describe the preventive and corrective measures for the most relevant welfare consequences*
		Aim: preventive and corrective measures for the most relevant welfare consequences for the previously defined transport scenarios per animal category are identified. Approach: Expert opinion via group discussion. Relationship with assessment question: this corresponds to the assessment question and is related to Sub-question 4 in which preventive and corrective measures are identified only for the most relevant welfare consequences.	Aim: Preventive and corrective measures are described Approach: Literature review. Relationship with assessment question: related to Sub-question 8

2.2.1. Experts' opinion

The data obtained from the literature and public consultation were complemented by the opinions of the EFSA experts. As described in Table 2, expert opinion was mainly used for the sub-questions requiring the identification of transport practices, WCs, ABMs, hazards, preventive and corrective or mitigative measures. Expert opinion was mainly elicited via discussion among EFSA experts. However, for the identification of the highly relevant WCs, an informal, structured Expert Knowledge Elicitation (EKE) was carried out.

As explained above (Sub-question 4), the mandate requested the identification of the highly relevant WCs for each of the defined animal transport practices.

The starting point was the list of 33 specific WCs identified under Sub-question 3 (for details see Section 3.1.1.3 of the protocol, EFSA AHAW Panel, 2022a). The exercise was carried out separately for each of the animal transport stages per species or animal category resulting from Sub-question 1.

The exercise consisted of selecting the highly relevant WCs out of these 33 per each of these combinations (species/animal category × transport stage).

For each combination, EFSA experts classified, based on an estimate of their magnitude, the 33 WCs into four categories of relevance: (i) non-applicable, (ii) slightly relevant, (iii) moderately relevant and (iv) highly relevant. Appendix A contains an example of this process. The magnitude of a WC was defined as the product of three parameters: severity, duration and frequency of occurrence (EFSA AHAW Panel, 2012). Owing to the lack of published data on these three parameters, the experts expressed their qualitative expert opinion on the magnitude of WCs.

Expert opinion is elicited in three phases:

1) First phase: the experts go individually through the list of welfare consequences and identify those that would fall in the 'non-applicable' or 'slightly relevant' categories. Their individual judgements are then be collated, and those WCs unanimously identified as belonging to these two categories are removed and not considered for further assessment. Those WCs for which there is no consensus whether they are considered 'non-applicable' or 'slightly relevant' remain for further assessment and require an open group discussion to find a consensus.
2) Second phase: the experts individually went through the list of remaining WCs and identified those that fell in the category of 'highly relevant". These were kept for further assessment. Similarly, as during the first phase in case discrepant opinions emerged, consensus was sought through group discussion.
3) Third phase: the experts are asked to rank individually all the remaining WCs in the list that are not already identified as highly relevant (and thus kept) or non-applicable or slightly relevant (and thus removed) from the highest to the least relevant. Their individual rankings are then discussed again in an open group discussion with the aim to assign the remaining WCs into the category 'highly relevant' or in the category 'moderately relevant'.

The Scientific Opinion only reports, for each of the defined animal transport stages, those WCs that were selected to be highly relevant from this exercise (since the mandate asks for the 'most relevant' WCs in each identified transport practice).

Expert opinion was also part of the syntheses involved in the development of the quantitative recommendations for specific conditions within the means of transport (space allowance, microclimatic conditions, development over time) relevant to the assessment.

2.2.2. Literature searches

As described in Table 2, literature searches were carried out for the sub-questions requiring the description of transport stages, WCs, ABMs, hazards, preventive and corrective or mitigative measures.

First broad searches of literature providing information on current practices on transport of the animal categories and species included in the 'free-moving' mandate were carried out. Restrictions were applied in relation to the date of publication, considering only records published after a previous EFSA Scientific Opinion on the topic (EFSA AHAW Panel, 2011).

Following the broad searches, more specific searches were carried out focusing on welfare consequences, ABMs, hazards, preventive and corrective or mitigative measures.

For pigs, the search results (general + specific) yielded a total of 1,910 (235 + 1,675) records that were exported to an EndNote library together with the relevant metadata (e.g. title, authors, abstract). Titles and abstracts were screened to remove irrelevant publications (e.g. related to species, processes and research purposes that were out of scope of this Opinion) and duplicates, and successively to identify their relevance to the topic. The screening led to 397 relevant records. Experts screened these papers and selected 223 for further assessment. Full texts were retrieved and made available to the experts.

The search terms were saved in Web of Science and rerun with any results (records) subsequent to 2021 screened and added to the pool of papers available to the experts. In addition, the experts selected relevant references starting from scientific papers, including review papers, book chapters, non-peer-reviewed papers known by the experts themselves, or retrieved through non-systematic searches, until the information of the topic was considered sufficient to undertake the assessment by the EFSA experts. If needed, relevant publications from before 2011 were considered.

3. Assessment

3.1. The transport of pigs in the EU

Transport of animals between MS and exports from the EU are recorded in the TRAde Control and Expert System (TRACES), which is the European Commission's multilingual online platform for sanitary and phytosanitary certification required for intra-EU trade and importation of animals, semen, embryos, food, feed, and plants (https://ec.europa.eu/food/animals/live_animals_en). However, movements inside MS (i.e. to slaughterhouses or between farms) are not recorded in this database (Rojek, 2021).

According to TRACES, around 35 million pigs were transported between MS in 2019, 33 million in 2020 and 25 million in 2021, across all means of transport. Road transport constituted the vast majority of total pig transport in these years.

3.2. Welfare consequences associated with transport of pigs

During the last decades, several scientific reviews (e.g. Cockram, 2007; Nielsen et al., 2011), textbooks (e.g. Grandin, 2019) and international organisations (e.g. WOAH, 2011) have described and discussed the consequences of animal transport in terms of animal welfare. In general, it is agreed that animal transport can lead to severe negative animal welfare consequences. Transport of animals is known as a complex stressor involving many aspects (related to the condition of the animals, their general biological characteristics, as well as the conditions under which the transport takes place, including journey duration), the majority of which to some extent may influence animal welfare. Thus, when analysed in detail, a highly complex picture emerges and transport stress must be considered as a multifactorial stressor.

Across the different stages of the transport of pigs, the following WCs were selected as highly relevant: group stress, handling stress, heat stress, injuries, motion stress, prolonged hunger, prolonged thirst, resting problems, restriction of movement and sensory overstimulation (Table 3). It is clear from this table that most transport stages involve several WCs.

For the purpose of this Scientific Opinion, the WC injuries, was created as a combination of the WCs 'Soft tissue lesions and integument damage' and 'Bone lesions' (see Section 3.1.1.3 of the protocol, EFSA AHAW Panel, 2022a).

Table 3: Welfare consequences selected as highly relevant per each of the transport stages involved in this Opinion

Welfare consequences and definitions		Transport stages			
		Preparation	**Loading/ unloading**	**Transit**	**Journey break**
Group stress	The animal experiences stress and/or negative affective states such as pain, fear and/or frustration resulting from a high incidence of aggressive and other types of negative social interactions, often due to hierarchy formation and competition for resources or mates.	X		X	X

Welfare consequences and definitions		Transport stages			
		Preparation	Loading/ unloading	Transit	Journey break
Handling stress	The animal experiences stress and/ or negative affective states such as pain and/or fear resulting from human or mechanical handling (e.g. loading/unloading).	X	X		X
Heat stress	The animal experiences stress and/ or negative affective states such as discomfort and/or distress when exposed to high effective temperature.	X	X	X	X
Injuries	The animal experiences negative affective states such as pain, discomfort or distress due to physical damage to somatic tissue types (bones, joints, skin muscles). This can be due to injuries or pathological changes.	X		X	X
Motion stress	The animal experiences motion sickness, stress and/or fatigue due to the forces exerted as a result of acceleration, braking, stopping, cornering, gear changing, vibrations and uneven road surfaces during transport.			X	
Prolonged hunger	The animal experiences craving or urgent need for food or a specific nutrient, accompanied by a negative affective state, and eventually leading to a weakened condition as metabolic requirements are not met.	X		X	X
Prolonged thirst	The animal experiences craving or urgent need for water, accompanied by an uneasy sensation (a negative affective state), and eventually leading to dehydration as metabolic requirements are not met.			X	X
Resting problems	The animal experiences stress and/ or negative affective states such as discomfort, and/or frustration due to the inability to lie/rest comfortably or sleep. (e.g. due to hard flooring or vibration during transport). This may eventually lead to fatigue.	X		X	X
Restriction of movements	The animal experiences stress and/ or negative affective states such as pain, fear, discomfort and/or frustration due to the fact that it is unable to move freely, or is unable to walk comfortably (e.g. due to overcrowding, unsuitable floors, gates, barriers).			X	X

Welfare consequences and definitions		Transport stages			
		Preparation	Loading/ unloading	Transit	Journey break
Sensory overstimulation	The animal experiences stress and/ or negative affective states such as fear or discomfort due to visual, auditory or olfactory under/ overstimulation by the physical environment.		X	X	

3.2.1. Negative affective states

The description of each WC reported in Table 3 refers to one or more negative states involving affective components (e.g. pain, fear, fatigue). These are the major negative affective states that derive from the occurrence of the WC, and that may potentially lead to animal suffering. A list and description of the negative states as derived from literature, and also described in the guidance protocol document (EFSA AHAW Panel, 2022a) is reported in Table 4.

Table 4: List and description of the negative states, that animals may experience, when exposed to at least one of the welfare consequences listed above

Negative affective state	Description
Boredom	Boredom is an unpleasant emotion including suboptimal arousal levels and a thwarted motivation to experience almost anything different or more arousing than the behaviours and sensations currently possible (adapted from Mason and Burn, 2011).
Discomfort	Discomfort can be physical or psychological and is characterised by an unpleasant feeling resulting in a natural response of avoidance or reduction of the source of the discomfort. Pain is one of the causes for discomfort, but not every discomfort can be attributed to pain. Discomfort in non-communicative patients is assessed and measured via behavioural expression, also used to describe pain and agitation, leading to discomfort being interpreted as pain in some conditions (Ashkenazy and Ganz, 2019).
Stress[1] & Distress	STRESS[1]: Stressors are events, internal or external to the body involving real or potential threats to the maintenance of homeostasis. When stressors are present, the body will show stress responses (biological defence to re-establish homeostasis – for example behavioural, physiological, immunological, cognitive, and emotional). Stress is a state of the body when stress responses are present (Sapolsky, 2002). DISTRESS: Distress is a conscious, negatively valenced, intensified affective motivational state that occurs in response to a perception that current coping mechanisms (involving physiological stress responses) are at risk of failing to alleviate the aversiveness of the current situation in a sufficient and timely manner (McMillan, 2020).
Fatigue	Physiological state representing extreme tiredness and exhaustion of an animal (EFSA AHAW Panel, 2020).
Fear	The animal experiences an unpleasant emotional affective state induced by the perception of a danger or a potential danger that threaten the integrity of the animal (Boissy, 1995).
Frustration	Negatively valenced emotional state consecutive to the impossibility to obtain what is expected or needed. Frustration is very often triggered by restriction of natural behaviours thus resulting in thwarted motivation to perform these behaviours.
Pain	An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage (Raja et al., 2020).

(1): The term stress does not describe a negative affective state in itself, but it is mentioned and defined in the table as it is a prerequisite of distress.

3.2.2. Definition and interpretation of ABMs for highly relevant welfare consequences during pig transport

Only a few studies have evaluated systems for the assessment of welfare during transport for livestock species, and – so far – no validated protocol for the assessment of pig welfare before, during and after transport has been described. Consequently, no benchmark values documenting optimal animal welfare status during or after transport exist to inform this Scientific Opinion. In addition, benchmark values documenting good animal welfare do not exist for any of the ABMs listed in this Scientific Opinion in relation to transport.

The feasibility of an ABM may be defined as the practicality to carry out an assessment of the ABM under field conditions. Feasibility does not relate to the sensitivity, specificity or repeatability of recording of an ABM. A feasible ABM for use during transport should be able to be recorded quickly, without using any specialised equipment or laboratory test, at a low cost, and with no (or only minimal) interference with normal operation procedures (Llonch et al., 2015). Llonch et al. (2015) divided feasibility into three categories: high (easy and quick recording without any special needs/tools), medium (extra time and/or space needed for recording), and low (not able to record under field conditions).

Some ABMs may have acceptable feasibility when it comes to recordings as part of research projects, but not when it comes to recordings during routine transport, especially in the transit stage. No studies have evaluated whether an ABM is of low, medium or high feasibility during animal transport. Feasibility is therefore not further addressed in this Scientific Opinion. A similar lack of knowledge exists with reference to sensitivity and specificity of ABMs in the context of animal transport and so these characteristics will not be dealt with in this Scientific Opinion.

One of the main feasibility challenges in relation to ABMs during transport is the access to, and visibility of, the animals during particular stages, especially the transit stage. It is very difficult, if not impossible to see all animals when in a livestock truck, for example. This problem can be partially overcome by the use of cameras and/or other types of sensors. However, the mere presence of cameras or sensors does not overcome all of these challenges, as data generated by such sensors need to be analysed in some way leading to an interpretation of the practice in question. Currently, technological tools within this area are under development outside the transport context (as described in Larsen et al., 2021), but not yet applicable in transport practice. This constitutes a gap in knowledge. Until sensors and associated interpretive or alarm systems are available at a practical level, the stage of transport appears to be the biggest influence on the feasibility of any ABM during animal transport. Another aspect of transport stress that may be monitored and mitigated in the future by use of sensor technology is motion stress caused by movements of the vehicle during the transit stage (as described by Morris et al., 2021).

During preparation, loading, unloading and journey breaks off the vehicle, the animals can be properly inspected, and ABMs in principle utilised. Among these could be visually recognised indicators, but potentially also auditory indicators or physiological biomarkers that can be obtained from, e.g. saliva, or even behavioural tests of, e.g. latency to drink from a bucket. At present, however, these potential indicators need further development and validation for use in animal transport. There is also a subset of ABMs that are not feasible during transport even when the animals can be inspected (Llonch et al., 2015). Examples of these are physiological indicators requiring invasive procedures. Tables 5–13 below contain information on the definition and interpretation of ABMs, including ABMs considered potential candidates for future inspection, as well as ABMs that so far have only been used in scientific studies underlying the conclusions of the Scientific Opinion.

i) ABMs for the assessment of the welfare consequence group stress

Table 5: ABMs selected for the assessment of group stress in pigs during preparation, the transit stage and journey breaks

ABM	Definition and interpretation of the ABM
Skin lesions and wounds	**Definition:** Tissue damage such as bruises, scratches, and wounds (EFSA AHAW Panel, 2012). **Interpretation:** Aggressive interactions between pigs lead to skin lesions.
Fighting	**Definition:** Negative social interactions such as biting, head-knocking and threatening, pushing at the side or chasing each other. **Interpretation**: Fighting is an aggressive behaviour occasioned by mixing of pigs from different social groups, competition for food, and lack of adequate space to respond submissively to a threat and to achieve full avoidance action and move away.

ABM: animal-based measure.

ii) ABMs for the assessment of the welfare consequence handling stress

Table 6: ABMs selected for the assessment of handling stress in pigs during preparation and loading/unloading

ABM	Definition and interpretation of the ABM
High-level vocalisations (screams)	**Definition:** Squealing or screaming, at group level when pigs are moved or manipulated (adapted from Welfare Quality®, 2009; Dalmau et al., 2009). **Interpretation:** Pigs are prone to scream when scared, forced to do something they do not want or exposed to pain. Electric goad use is associated with such vocalisations (Correa et al., 2010).
Falling	**Definition:** Loss of balance, in which part(s) of the body (beside legs) are in touch with the floor (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Pigs may fall on the ramp or in barn/truck as a result of forceful handling, behaviour of other pigs, slippery flooring, steepness or obstacles.
Slipping	**Definition:** Loss of balance, without (a part of) the body being in touch with the floor (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Slipping occurs when pigs are forced to move rapidly on an inadequate surface.
Refusal to move forward	**Definition:** An animal that stops for at least two seconds not moving the body or head (freezing) or that refuses to move when coerced by the operator (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Pigs refusal to move forward when exposed to handling stress or loading/unloading area is not well designed (angle, depth of slope, flooring, lack of foot battens or lateral protection, etc.).
Mounting/overlapping	**Definition**: Pig mounts another pig, with its front legs on the back of the other pig (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Insufficient space on the ramp during loading and unloading due to inadequate group size in tight/narrow spaces and rough handling may lead to mounting and/or overlapping.
Post-mortem carcass lesions	**Definition:** Skin damages on carcases that are assessed in the slaughterhouse subjectively along the dressing line by using different photographic scales. The assessment can be conducted as a whole or separately in different parts of the carcass, such as head/shoulder, middle/loin, and ham (Faucitano, 2001). **Interpretation:** Post-mortem carcass lesions are considered as evidence of poor handling and inadequate facilities at farm and during all stages of loading/ unloading.

ABM: animal-based measure.

iii) ABMs for the assessment of the welfare consequence heat stress

Table 7: ABMs selected for the assessment of heat stress in pigs during preparation, loading/ unloading, transit and journey breaks

ABM	Definition and interpretation of the ABM
Respiratory rate	**Definition:** Breathing rate. Usually measured by counting the movements of the flank from direct observation and converting this into breaths per minute (BPM). **Interpretation:** Heat stress leads pigs to show increased respiration rates until reaching panting. Respiration rate increases with body temperature in order to maintain homeostasis (Brown-Brandl et al., 2001; Bjerg et al., 2020).
Rectal temperature	**Definition:** A proxy for the body temperature of the pig as measured by a thermometer inserted in the rectum (Yundong, 2012). **Interpretation:** Body temperature rises during heat stress when the physiological and behavioural mechanisms for the dissipation of heat can no longer maintain equilibrium because of heat gained from excessive environment heat combined with metabolic heat production.

ABM	Definition and interpretation of the ABM
Panting	**Definition:** Short breathing carried with the mouth open (Bracke et al., 2020). The first phase of panting is characterised by rapid, shallow breathing called thermal polypnea, associated with an increase in respiratory rate. This shifts to a second phase characterised by slower and deeper breathing, named thermal hyperpnea characterised by an increase of alveolar ventilation rate. **Interpretation**: Evaporation of water by panting is the primary form for pigs to loose heat at high temperatures (Huynh et al., 2005). Panting is considered a physical sign of stress and it is associated with dissipation of excess heat and/or fatigue.
Skin discoloration	**Definition:** Changes from light to redder colour of the skin with a transient blotchy appearance (Kephart et al., 2010). **Interpretation**: It is considered a physical sign of stress due to the effort related to physical activities such as loading/unloading (Pilcher et al., 2011).

ABM: animal-based measure.

iv) ABMs for the assessment of the welfare consequence injuries

Table 8: ABMs selected for the assessment of injuries in pigs during preparation, transit and journey breaks

ABM	Definition and interpretation of the ABM
Skin lesions and wounds	**Definition:** Tissue damage such as bruises, scratches, and wounds (EFSA AHAW Panel, 2012). **Interpretation:** Damage may be caused by biting among pigs and sharp or abrasive structures in handling facilities or vehicles.
Lameness	**Definition**: Clinical manifestation of locomotory changes characterised by alterations from normal gait or posture and potential reduced mobility (Nalon et al., 2013) **Interpretation:** Most lameness is a consequence of pain but it can also occur from mechanical defects resulting in physical incapacity. Behavioural changes associated with lameness indicate attempts by the animal to protect the affected limb from pain and further injury. Lameness is relevant for the welfare of the pigs, not only as indicator of pain, but also reduces the capacity of the animal to cope with the environment (Dalmau et al., 2010).
Post-mortem carcass lesions	**Definition:** Skin damages on carcases are assessed in the slaughterhouse subjectively along the dressing line by using different photographic scales. The assessment can be conducted as a whole or separately in different parts of the carcass, such as head/shoulder, middle/loin, and ham (Faucitano, 2001). **Interpretation:** Post-mortem carcass lesions are considered as evidence of poor handling and inadequate facilities at farm and during all stages of loading/unloading.

ABM: animal-based measure.

v) ABMs for the assessment of motion stress and sensory overstimulation

Table 9: ABMs selected for the assessment of motion stress and sensory overstimulation in pigs during loading/unloading and in transit

ABM	Definition and interpretation of the ABM
Foaming at the mouth	**Definition:** An excess of saliva mixed with air or gasses to create a foam. **Interpretation**: Hypersalivation at the mouth is a symptom of travel sickness and is often associated with chomping and retching (Randall and Bradshaw, 1998).
Vomiting	**Definition:** Vomiting is a protective response and coordinated reflex where upper gastrointestinal tract contents are forcefully ejected from the mouth (Santurtun and Phillips, 2015). **Interpretation**: During journey, pigs may vomit as a sign of motion sickness (Santurtun and Phillips, 2015).

ABM	Definition and interpretation of the ABM
Falling	**Definition:** Loss of balance, in which part(s) of the body (beside legs) are in touch with the floor (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Pigs may fall on the ramp or in barn/truck as a result of forceful handling, behaviour of other pigs, slippery flooring, steepness or obstacles.
Heart rate (HR)	**Definition:** The number of heart beats per unit time, usually per minute. **Interpretation**: The response to stressors leads to a secretion of catecholamines that prepare the body to respond, by for example, increasing heart rate (Von Borell, 2007). HR is affected by factors other than acute stress such as the exercise associated with movement in response to handling and loading. HR reflects the activity of the sympathetic branch of the autonomic nervous system and therefore is an indicator of the stress response and of the animal's emotional reactivity.
Plasma cortisol	**Definition:** When a threat is perceived by an animal, the hypothalamic–pituitary–adrenal (HPA) axis gets activated resulting in release of several hormones that lead to the synthesis of glucocorticoids such as cortisol in the adrenal cortex and its consequent increase into the bloodstream (Turner and Tilbrook, 2006). **Interpretation:** Plasma cortisol concentration increases from the moment of loading an indirect measure of the stress experienced by an animal when exposed to adverse conditions during the initial part of a journey (Miranda-De La Lama et al., 2009). With increased journey duration feedback mechanisms can reduce its concentration and the plasma cortisol concentration may no longer reflect the continued perception of pigs. Continued hypothalamic stimulation results in the continual secretion of corticotropin-releasing hormone even though plasma cortisol concentration may have fallen (Smith et al., 2003).
Post-mortem carcass lesions	**Definition:** Skin damages on carcases are assessed in the slaughterhouse subjectively along the dressing line by using different photographic scales. The assessment can be conducted as a whole or separately in different parts of the carcass, such as head/shoulder, middle/loin, and ham (Faucitano, 2001). **Interpretation:** Pigs with lesions might have hurt themselves during the journey.

ABM: animal-based measure.

vi) ABMs for the assessment of the welfare consequence prolonged hunger

Table 10: ABMs selected for the assessment of prolonged hunger in pigs during preparation, while in transit and during journey breaks

ABM	Definition and interpretation of the ABM
Aggressive behaviour	**Definition:** Negative social interactions such as fighting, head-knocking, threatening, and biting (Welfare Quality®, 2009). **Interpretation**: Negative social interactions occur during most transport stages due to mixing of unfamiliar pigs, and are generally increased in pigs that have been food deprived.
Latency to feed after unloading	**Definition:** A quantification of the time interval from unloading and until the animal is observed eating for the first time **Interpretation:** A short latency to eat is a reflection of a high motivation to eat. Can be affected by other factors such as fear.
Competition for feed	**Definition:** Occurs when more than one pig tries to access a food source or one pig monopolise the feed. Usually, aggression is seen. **Interpretation:** When pigs start to compete for access to feed, it is a sign of increased motivation to eat.
Plasma glucose	**Definition**: Glucose is a monosaccharide, which can be stored as a multi-branched polysaccharide, called glycogen, in skeletal muscle and the liver (Terlouw and Bourguet, 2022). In monogastric animals, like pigs, blood glucose levels reflect the nutritional status of the animal (Shaw and Tume, 1992).

ABM	Definition and interpretation of the ABM
	Interpretation: Food deprivation diminishes plasma glucose levels and glycogen content in the liver and muscle (Knowles, 1999). The effects on muscle energy depletion at slaughter and meat quality are only visible if glycogen levels reach a certain, low threshold (55 μmol glucose equivalents/g fresh muscle tissue; Terlouw et al., 2021).
Plasma free fatty acids (FFA)	**Definition**: Free fatty acids (FFA) are elongated hydrocarbon chains with a terminal carboxylate group and are stored in body fat. Jointly with glucose, FFA are degraded via specific pathways to yield energy (Terlouw and Bourguet, 2022). **Interpretation**: Increased concentrations of FFA may indicate increased breakdown of fat in response to undernutrition (Shaw and Tume, 1992). When glucose levels are relatively low, plasma FFA levels, and their uptake and oxidation by the muscles increase (Romijn et al., 1995). Food deprivation increases FFA in blood (Brown et al., 1999).
Muscle glycolytic potential	**Definition**: Muscle glycogen can be measured alone or within the glycolytic potential (GP), which is a measure of all compounds present in the muscle that can be converted into lactic acid. The GP is an indicator of the muscle's capacity for *post-mortem* glycolysis, and, therefore, of the potential extent of muscle pH decline after slaughter (Monin and Sellier, 1985). **Interpretation**: Lower muscle GP values are indicative of muscle energy use and depletion after long-term stress due to, among others, longer period without feed, e.g. longer post-transport lairage (Rocha et al., 2015).

ABM: animal-based measure.

vii) ABMs for the assessment of the welfare consequence prolonged thirst

Table 11: ABMs selected for the assessment of prolonged thirst in pigs during preparation, transit and journey breaks

ABM	Definition and interpretation of the ABM
Plasma osmolality	**Definition**: Measurement of the concentration of solutes in blood, used as indicator of dehydration (Clemens et al., 1986). **Interpretation**: Lack of access to water coupled with physical exercise and heat during travel causes hypertonic dehydration which is expressed in an elevation of plasma osmolarity (Parrott et al., 1987). This indicates hypertonic dehydration which occurs when water loss is proportionally greater than electrolyte loss, with water passing from the cell to the extracellular space as a compensatory mechanism (Walz et al., 2012).
Packed cell volume	**Definition:** The ratio of the volume occupied by packed red blood cells to the volume of the whole blood as measured by a haematocrit **Interpretation:** Increases in response to dehydration but changes are confounded by potential splenic contraction due to stress, and loss of red blood cells (Turner and Hodgetts, 1959)**.**
Plasma total protein concentration	**Definition**: Concentration of plasma proteins such as albumin and globulins in blood plasma volume. **Interpretation**: A journey in hot conditions, high densities and without water intake will cause animals to lose fluids and consequently have a marked elevation of this indicator.
Intake of water after unloading	**Definition:** Intake of water during the initial hours after unloading, including latency to drink. **Interpretation:** Shows the transport-induced thirst threshold as a function of drinking time (Pascual-Alonso et al., 2017).

ABM: animal-based measure.

viii) ABMs for the assessment of the welfare consequence resting problems

Table 12: ABMs selected for the assessment of resting problems in pigs during preparation, in transit and journey breaks

ABM	Definition and interpretation of the ABM
Time spent standing	**Definition:** Time that pigs maintaining an upright position during transport. **Interpretation:** Pigs tend to spend more time standing during a transport stage in comparison with housing conditions because of the impossibility of lying down due to lack of space and/or excessive vibration-motion of the truck.
Falling	**Definition:** Loss of balance, in which part(s) of the body (beside legs) are in touch with the floor (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Falling during transport occurs when there is a slippery floor surface, the driving style is not adequate, or animals are fatigued.
Sitting	**Definition:** Pigs have their hind quarters in contact with the trailer floor, and are propped up with weight on the fore legs. **Interpretation:** When space is limited, more sitting behaviour may be observed, as there is insufficient space for all pigs to lie. Sitting is a postural adjustment and space saving behaviour that has been associated with reduced space provision during transport (Urrea et al., 2021).
Lying behaviour after unloading	**Definition:** Pigs adopting a lying position, removing weight from their legs. Pigs may adopt a lying posture on their sternum, their lateral side, or be semi-recumbent. **Interpretation:** An increased number of pigs lying down and additionally, adopting a lying posture rapidly after unloading is associated with greater fatigue during the journey (Urrea et al., 2021). There may also be a reduction in other behaviours (drinking, fighting), with pigs prioritising lying down (Dalla Costa et al., 2016; Urrea et al., 2021).
Blood creatine kinase	**Definition:** Creatine kinase (CK) measured in blood (serum or plasma) is an enzyme that is increased with muscle activity and injury (Hody et al., 2011). **Interpretation**: CK has been used as a measure to indicate stress and fatigue in pigs during transport. Pigs transported with lower space allowances show raised levels of CK, suggesting increased fatigue associated with a reduction in resting and increased posture adjustments/requirements to stabilise themselves as opposed to rest (Gerritzen et al., 2013; Urrea et al., 2021).

ABM: animal-based measure.

ix) ABMs for the assessment of the welfare consequence restriction of movements

Table 13: ABMs selected for the assessment of restriction of movements in pigs during transit and journey breaks

ABM	Definition and interpretation of the ABM
Mounting/ overlapping	**Definition**: Pig mounts another pig, with its front legs on the back of the other pig (Dalmau et al., 2009; Welfare Quality®, 2009). **Interpretation:** Insufficient space on the ramp during loading and unloading lead to mounting and/or overlapping. Mounting is considered an aggressive behaviour showed by both male and female often related to the restriction of movement. Overlapping during transport occurs when the pigs are not able to walk and reach drinkers, and when are not able to be lying in full lateral recumbency

ABM: animal-based measure.

3.3. Preparation of pigs for transport

Across pig categories as well as journey types and journey durations, the preparation of pigs for transport may differ substantially. The fact that the place of departure may be a farm of origin, assembly centre, market or auction, depending on the type of pigs and MS, adds significantly to this variability. Regardless of the variability, preparation is an important phase in terms of animal welfare, as careful preparation of pigs for transport can substantially improve the welfare impact of transport.

For the purpose of this Opinion, the preparation phase involves all types of actions and animal management that take place during the interval from the decision to transport pigs until the initiation of loading of the pigs onto a vehicle or other means of transport. In effect, in this Opinion, the preparation of pigs for transport essentially involves the gathering of the animals to holding facilities and the keeping of them there prior to transport itself. Assessment of fitness for transport is included in the preparation stage. The loading of animals into the transport vehicle is covered in Section 3.4. For matters related to logistics, paperwork and planning, such as for example route planning, readers are recommended to check recent recommendations from the EU Transport Guides (Consortium of the Animal Transport Guides Project (CATGP, 2017) (2017-rev1), 2018). Recommendations for facilities at the various types of premises in question can also be found in the Transport Guides. These issues will not be covered in the Scientific Opinion.

3.3.1. Current practice

Below, the current practice when pigs are prepared for transport is described, including aspects relevant for weaners transported for further fattening and transport of finisher pigs to slaughter. When relevant, reference is made to cull sows and boars. The animal category cull sows is also covered in Section 3.7.

Depending on the category of pigs, farmers typically send full loads (weaners shipped to other MS, for export, or farm-to-farm journeys within the same MS, and finishers destined for slaughter) or only fractions of a load (cull sows and/or boars). This structural difference has significant effects on the preparation of the pigs for transport in terms of, for example, biosecurity. In addition, whether pigs are sent for further fattening or to slaughter has significant effects on the preparation in terms of pre-transport fasting. Another significant factor affecting preparation, and potential WCs of this stage, is whether the pigs are supposed to depart from an assembly barn, a CP, auction or similar, or whether the journey is directly from farm-of-origin to destination. In this Opinion, the use of CPs as a journey break is treated in Section 3.6.3. Irrespective of the category of pigs, or types or duration of journeys, a central part in the preparation for transport is the check of fitness for transport.

As mentioned, pigs can be collected from farms-of-origin as full loads or as smaller groups. When collected as full loads, an empty, clean vehicle can approach the building of the farm and collect the pigs from their home pens or from designated 'pick-up' pens in separate sections of the building or separate buildings housing the pigs selected for transport. When pigs are collected in smaller groups, typically vehicles will visit more than one farm on the route to the slaughterhouse. In this case, for biosecurity reasons, farmers may place the pigs in some type of vehicle or portable pen, outside the farm buildings holding the production herd, and leave the pigs there to be picked up (Figure 1).

Figure 1: Sows kept in a 'pick-up vehicle' outside farm buildings, near a public road, awaiting the pick-up by the truck taking them to the slaughterhouse. Photos: Louisa Gould, Aarhus University

3.3.2. Highly relevant welfare consequences

The highly relevant WCs during the preparation stage are group stress, handling stress, heat stress, injuries, resting problems and prolonged hunger. The latter will not occur during the preparation stage, but actions there predispose pigs to this WC at later transport stages. Below, hazards (in bold) and preventive measures (PRE), corrective and mitigating measures are described.

i) Group stress and injuries

Group stress is probably the most relevant WC for pigs during the preparation stage. Injuries are often the physical outcome of group stress in pigs, and therefore these two WCs are combined here.

Mixing unfamiliar pigs: Irrespective of subsequent journey type, as described by the EFSA AHAW Panel (2020), when pigs are sorted for transport, and mixed with non-penmates, there is a risk of increased aggression as the animals start to establish a new hierarchy. Goumon and Faucitano (2017) reviewed pre-transport on-farm procedures in terms of animal welfare of finishers and stated that the initial departure from the finishing pen is stressful as it involves alteration of the social environment through separation from the familiar group, which is one of the factors that influences aggressive behaviour.

- PRE: To prevent this hazard, pigs that are not familiar with each other should not be mixed.

The use of 'pick-up' pens (also termed shipping pens): Across the EU pick-up pens are used in some countries. Only very few studies have dealt with this type of pen, and with the pre-transport welfare of pigs in pick-up pens (sometimes called shipping pens as in Goumon and Faucitano (2017)), 'temporary lairage pens' or 'pick-up vehicles', but some studies are available on related issues such as the use of pre-sorting before pigs are sent to slaughter (Gesing et al., 2010). The use of pick-up pens implies mixing of pigs from different finishing pens which may be one of the major sources of fighting-type lesions observed on carcasses (as reviewed by Brandt and Aaslyng, 2015). Similar findings have been reported after mixing of cull sows in pre-transport pick-up pens (Herskin et al., 2020a), and during stays in stationary pick-up vehicles, considerable levels of aggression were reported (Herskin et al., 2017). These findings suggest that the use of pick-up pens may be of welfare concern. It is, however, not known whether resources can be provided to the pens, thereby reducing the level of aggression. In addition, it is not known whether the use of pick-up pens changes the total level of post-mixing aggression shown in pick-up pens plus during the journey as such. It is likely that all categories of pigs, will, at least to some extent, experience aggression when kept in pick-up pens, and thus risk being challenged in terms of animal welfare and fitness for transport in the hours before being picked up by the transport vehicle.

- PRE: To prevent the hazard of post-mixing fighting, the pick-up pen size should be adapted to the compartment size in a transport vehicle (Goumon and Faucitano, 2017), so that pigs will not need to be re-mixed when entering the means of transport. In addition, the pick-up area should be provided with proper ventilation.

Corrective/mitigating measure of group stress and injuries

If pigs are mixed, the consequences in terms of aggression and injury can be mitigated by ensuring enough space for subordinate individuals to move away from aggressive ones. This is further improved, if the place where the pigs are kept are provided with hiding places, such as half walls. In addition, the WC can be mitigated by the provision of ample resources, such as rooting materials and water, and measures to keep the microclimatic conditions within the thermal comfort zone (TCZ) of the animals. In the Scientific Opinion concerning the protection of pigs (EFSA AHAW Panel, 2022b), a pen concept including many of such mitigating measures are introduced and called a mixing pen (Figure 2).

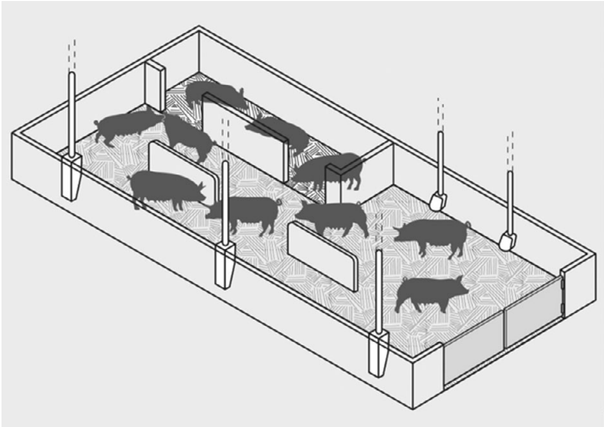


Figure 2: Example of a mixing pen, where pigs are offered mitigating measures of group stress induced by mixing (EFSA AHAW Panel, 2022b)

ii) Handling stress

Depending on how the pigs are prepared for transport, handling stress may be a highly relevant WC, the hazards of which are:

Inexperienced, untrained or aggressive handlers: Insufficient knowledge of handling issues by the handler is regarded as the main risk for impaired animal welfare during handling of pigs.

- PRE: A crucial preventive measure is the training of handlers. Education and training leads to the necessary knowledge on the impact of a person's work on animal stress, fear, and related injuries, and on the main clinical signs to judge the state of the animals before loading. In order to move pigs, it is advantageous if staff understands the behaviour of pigs, and e.g. use the flight zone and point of balance principle. The use of flags, paddles or pig boards to move the pigs in small groups using their natural 'following' behaviour (Grandin, 2016a,b) will help to avoid the use of electric goads, which lead to fear and pain, and may lead to distress if used repeatedly.

Time pressure: The consequences of time pressure on handlers mean a risk of handling getting rougher, and pigs will be more prone to the risks of slipping, falling and skin lesions (Wilhelmsson, 2022).

- PRE: Staff have to avoid time pressure in order to move pigs in a quiet and calm way.

Inappropriate handling methods and devices: When devices to stimulate animals to move, i.e. boards and rattles, are used roughly (with excessive force, causing damage) handling stress (and potentially injuries, either as a consequence of animals falling or trying to escape) is induced. Another consequence of the rough handling is lesions that are recognisable post-mortem (Faucitano, 2001), sometimes called human-inflicted lesions (Nielsen et al., 2014).

- PRE: Handlers should be trained in non-aversive handling techniques.

Hours fasted before loading: When fasting is prolonged, pigs may be more difficult to handle at loading (Dalla Costa et al., 2016; Acevedo-Giraldo et al., 2020), and the increased frustration and agitation caused by hunger are the likely causes for these behavioural changes as an extended fasting period may cause hunger and aggressiveness (as reviewed by Faucitano, 2018). There are, however, also data suggesting that pigs fasted for 18 h were less aggressive during post-transport lairage than non-fasted pigs (Dalla Costa et al., 2016) and also studies reporting no physiological stress responses after handling of pigs with full stomachs versus fasted pigs (Faucitano et al., 2006). Importantly, the available data on effects of pre-transport fasting on behaviour and welfare of pigs, are all from studies of finishers. Whether there are effects of fasting on, e.g. aggression in cull sows – where a significant proportion is lactating and used to a high feeding level (Thodberg et al., 2019) - is not known.

- PRE: Pre-loading fasting duration should not be too long. See recommendations on fasting time in Section 3.3.2 [prolonged hunger] below.

Corrective/mitigating measures of handling stress

If aggressive or rough handling is observed, the handler should be removed from the place or receive training in situ.

iii) Heat stress

The main hazards that can lead to heat stress during this stage of transport are listed below, together with preventive measures, and corrective or mitigating measures for the WC. More detailed information on the influence of microclimatic conditions on pigs can be found in Section 3.5.3.1 dealing with heat stress during the transit stage.

High effective temperature: Heat stress in pigs is mainly due to high air temperature, but is intensified by high humidity, solar radiation (lack of shade), low air movement, and by metabolic heat. Pigs may become sunburned if placed in direct sunlight for hours in, for example, a pick-up pen or similar facility. High ambient temperature accompanied by high humidity causes discomfort and enhances the stress level.

- PRE: To prevent high temperatures, avoid putting pigs into pick-up facilities without a roof. The facilities should be designed to allow for a breeze to pass through, and the warmest hours of the day should be avoided. When stationary, pick-up pens and vehicles should be placed in shaded areas.

Insufficient pre-transport water provision: If animals have not been provided with water during the preparation stage, there is an increased risk of heat stress.

- PRE: Animals should be given *ad libitum* access to water until the moment of loading.

High stocking density: Keeping pigs in pick-up facilities at high stocking density can increase the risk of heat stress during the preparation stage.

- PRE: Under hot conditions, lowering stocking density during preparation will help prevent heat stress.

Corrective/mitigating measure of heat stress

Animals spotted before loading showing signs of heat stress, should not be loaded. Affected animals should be moved to a place with shade, and ventilation (fan) and water should be provided with no restrictions. Animals can be cooled down using water sprinklers, showers or equivalent. Animals should be inspected before re-starting the loading to ensure they are fit for transport.

iv) Prolonged hunger

Unless pigs are fasted extensively before initiation of transport, it is unlikely that they will experience prolonged hunger during this stage of transport. However, as the feeding level during the preparation stage is highly influential for the level of hunger during the later transport stages, and thus can predispose pigs for prolonged hunger there, it is also mentioned here. Corrective and mitigative measures are described in Section 3.5 covering the transit stage.

Hours fasted before loading: Regarding pre-transport feeding, quite large differences exist between categories of pigs being transported for slaughter or for further fattening. Before being sent to slaughter, pigs will typically be fasted for hours while still on-farm. As recently described by EFSA AHAW Panel (2020), fasting is done to reduce gut content and prevent release and spread of bacterial contamination through faeces during transport and lairage, as well as through the spillage of gut contents during carcass evisceration. Fasting before slaughter, within reasonable limits, can also be beneficial to animal welfare as it may prevent pigs from vomiting in transit (due to motion sickness) and from developing hyperthermia (Averós et al., 2008). Survey studies have also found increased risk of in-transit mortality in pigs that were not fasted before transport (Guàrdia et al., 1996; Averós et al., 2008), but, as reviewed by Zurbrigg et al. (2017), the use of survey type studies means that the fasting per se may not be the causal factor of the mortality as this management tool is most probably confounded by other pre-slaughter management, such as pig sorting method. The physiological mechanism as to why fasting can reduce transport mortality has not been well studied (as discussed by Zurbrigg et al., 2017).

Kephart and Mills (2005) reported that feed takes 4–8 h to be absorbed by the small intestine after ingestion, where most nutrients enter the blood 9 h post-ingestion, thereby feed eaten within the last 10 h will remain as gut-fill. In his review of pig welfare during transport, Warriss et al. (1998)

estimated a rate of loss in body weight of ~ 0.2% of liveweight per hour. Part of this is urine and faeces, but carcass and liver weight reduction, reflecting loss of body reserves, begins 9–18 h after the last meal. Associated with the liver weight loss is a reduction in liver glycogen content. This follows a logarithmic pattern (Warriss and Bevis, 1987), so that very little remains after 24 h, over 2/3 having been lost in the initial 12 h. According to Warriss et al. (1998), it is likely that pigs are feeling very hungry at this time.

- PRE: Irrespective of whether pigs are transported for slaughter or for further fattening, pre-loading fasting duration should not be too long and should be appropriate for the journey duration, the pig category as well as take into consideration whether pigs are transported for slaughter or for further fattening/production. See recommendations on fasting time in Section 3.5.3.3.

v) Resting problems

Depending on the duration of preparation, resting problems might and might not develop during this stage. However, if pigs lack the opportunity to rest during the preparation stage, they will be predisposed to develop resting problems during later transport stages (Faucitano and Goumon, 2018). Therefore, the hazards for the development of resting problems connected to the preparation stage are assessed here, whereas corrective/mitigating measures are assessed in Section 3.5 covering the transit stage.

Insufficient space: When stocking density in pick-up facilities is too high, the animals do not have the space to lie down undisturbed, increasing the risk of resting problems during preparation.

- PRE: Depending on the duration of the preparation stage, pigs should be provided with enough space to allow them to rest, as described in detailed in quantitative examination of the space requirements (Section 3.5.3.2).

3.3.3. Fitness for transport

3.3.3.1. Introduction

Throughout the scientific literature, it is agreed that – in terms of animal welfare – making sure that animals are fit for transport before departure is of utmost importance (Grandin, 2001; Cockram, 2019). However, currently no agreed scientific definition of the concept of fitness for transport exists (as discussed by Herskin et al., 2021).

Animals sent for slaughter with pre-existing conditions are more likely to die in transit, become non-ambulatory, or be condemned as unfit for human consumption upon arrival at the slaughterhouse (Lambooij, 2014; Cockram, 2019; Dalla Costa et al., 2019). Unfit pigs, i.e. pigs unable to move or keep balance, showing respiratory distress, prolapsed uterus or rectum, profuse and continuous bleeding, in late pregnancy, or having just given birth, should not be loaded for transport as these poor health conditions make them weak and with less chance to cope with extended feed deprivation and to move away from aggression. In addition, the animals will be more likely to lose balance due to sudden stops or accelerations or changes of direction of the transport vehicle (Faucitano and Raj, 2022). Based on data collected in a survey of more than 300 loads transported to three Brazilian slaughterhouses, Dalla Costa et al. (2019) reported that of the 0.38% pigs identified as non-ambulatory after transport, half of them were already in this condition at the farm before loading. The authors also calculated a 1.32 times greater risk of DOA (Dead-On-Arrival) in pigs that were non-ambulatory or presenting hernias or arthritis at loading on the farm.

Thus, if animals are not properly inspected, and unfit animals are allowed to enter the logistic chain, it is a hazard for their welfare, predisposing them to different WCs during the journey, and potentially leading to negative affective states such as discomfort, pain and suffering. Typical characteristics leading to animals being unfit for transport are related to health impairment, but some characteristics rendering animals unfit for transport do not directly relate to health, but to certain age groups or certain stages of the production cycle.

The criteria and circumstances leading to a decision of 'unfit for transport' probably vary considerably across the different categories of pigs, thereby posing extra challenges for the professionals involved in decision-making: farmers, livestock drivers, veterinarians, and competent authorities, as well as posing challenges to the welfare of pigs that may be transported despite being unfit for the intended journey.

Based on the above, it is clear that making an assessment of fitness for transport is not simple. Studies in pigs have reported doubt in the decision-making of involved professionals (Thodberg et al., 2020; Herskin et al., 2020b). In cattle, a comparison between and within three different professional groups (livestock drivers, veterinarians and farmers) regarding fitness for transport of dairy cows, showed at best moderate agreement (Dahl-Pedersen et al., 2018). Hence, in order to prevent the significant welfare hazard of allowing unfit animals to enter a means of transport, it is highly important that the inspection is carried out correctly. If the concept of fitness for transport is not well-defined, if guidelines for fitness of transport are not comprehensive and broadly available, if professionals involved are not properly educated, and if questions about responsibility are present, the risk of animals entering a means of transport as unfit will be higher.

From a scientific point of view, the concept of fitness for transport as such has received limited attention, and at present, thresholds for ABMs as indicators of animals being unfit for transport have most often not been established or validated. If pigs are to be fully protected from the consequences of being transported, while in reality unfit for transport, knowledge about the risk associated with transport of animals with a number of conditions potentially leading to negative affective states (e.g. lameness, open wounds, mastitis in sows), as well as the establishment of ABMs useful to identify these and their thresholds (suitable for use across professional groups), are needed.

3.3.3.2. Assessment of fitness for transport in pigs

To assess the fitness of pigs for transport, they should be observed to detect potential clinical signs of illness and evaluate their behaviour, posture, gait, respiration and discharges. When necessary, pigs should be caught and examined in detail. As described by the EU Reference Center for Animal Welfare of Pigs (EURCAW, 2021), the diseases that limit the coping capacity of pigs during transport are, for example, cardiac issues (pericarditis, endocarditis), respiratory diseases (pneumonia, pleurisy), locomotory disorders and infections (abscesses, metritis, nephritis, etc.) (Cockram, 2019; Ritter et al., 2020). In addition, transport- or stress-related myopathies observed in fast-growing pig breeds or lines (Zurbrigg et al., 2017; Semenova et al., 2019) may also challenge the fitness for transport of pigs. Below, we review other examples of relevant clinical conditions of pigs.

- *Conditions leading to pigs being unfit for transport*

As reviewed by Cockram (2019), if, before transport, a pig has a **clinical condition that is painful,** transport will almost certainly aggravate the pain and may lead to suffering. Movement of, or pressure on, a painful area of inflammation, such as an arthritic joint, causes additional pain. Therefore, movement of body parts during loading, unloading, in response to vehicular movements or behaviour of other animals, and during postural changes, is likely to cause movement of the sensitive tissue and result in additional pain. Animals should not be transported with a non-stabilised fracture as this will cause additional pain and may lead to suffering. Bone fractures are painful; mechanical pressure applied to the fracture site, or movement and mechanical distortion of fractured bone causes pain (Herskin and Di Giminiani, 2018).

Lameness is common in pigs (Kilbride et al., 2009) and can be detected using gait scoring (as done by Fogsgaard et al. (2018) in sows prior to transport). When a pig appears lame or is reluctant to walk, it is most likely experiencing pain. Prolonged standing and efforts to maintain stability when the vehicle or other animals move, are likely to cause the condition of a lame animal to deteriorate during a journey (as documented by Thodberg et al. (2019) after transporting sows to slaughter). To be fit for transport, a pig must be able to stand, bear weight on all of its legs, and be able to adjust footing to maintain balance during the journey. The pig must also be able to walk up and down ramps at the start and the end of the journey (Faucitano and Raj, 2022).

One clinical condition that is relatively prevalent in weaners and finishers is **umbilical outpouchings** (Hovmand-Hansen et al., 2021a), often termed hernias, which is the popular name used to describe outpouchings on the ventral aspect of the abdominal wall of pigs. The outpouchings may cover several types of underlying pathology, e.g. cysts, abscesses and fibrosis (Hovmand-Hansen et al., 2021b), and true hernias (when abdominal viscera pass through weak areas in the inguinal ring or the navel without breaking through the skin) are only one type (Andersen et al., 2014). As reviewed by the EURCAW (2021), the general condition of the pigs with umbilical outpouchings vary from completely normal to un-thriving and depressed, with or without signs of pain. The mobility of the pigs might be limited by the outpouchings depending on their size and location and the underlying pathology. In addition, contact between the outpouching and the flooring (when lying or, for very big outpouchings, also when moving) may result in skin wearing off, and lead to the formation of sores. In the worst case, the outpouching may rupture. Under transport conditions, it is likely that pigs with umbilical outpouchings are in an increased risk of injury and rupture, as compared to healthy pigs, if piling or some degree of overlying occurs in the vehicle. However, the effects of umbilical outpouchings on behaviour and welfare of pigs are not fully understood (Schild et al., 2015a,b). Hernias are described in the practical guidelines to assess fitness for transport of pigs, published as part of the European research project 'TransportGuides' (Consortium of the Animal Transport Guides Project (CATGP, 2017) (2017-rev1), 2018). According to these guidelines, outpouchings should be considered serious, regarding fitness for transport, if they are more than 15–20 cm wide and present sores. Some authors reported a greater risk of death (1.32 times more) during transport in pigs presenting hernias before loading (Dalla Costa et al., 2019). However, it is not specified whether the 15–20 cm threshold covers the span of pig live weights typically transported (from weaners to breeding boars) and no studies have successfully validated this threshold in terms of fitness for transport of pigs.

Even though several sources mention physiological weakness as a reason for not transporting animals, it is not specified how the term should be operationalised. Some characteristics rendering animals unfit for transport do not directly relate to health issues, but to certain age groups or certain stages of the production cycle (EURCAW, 2021). One such potential candidate is **lactating females.** Thodberg et al. (2019) focused on the proportion of cull sows sent for slaughter with engorged udders due to ongoing milk production, caused by a very recent weaning of their litters. In the days before weaning, modern prolific sows produce a substantial amount of milk (Williams et al., 2013), and this process is not stopped until days after weaning. However, the accumulation of milk in the porcine udder, and potential consequences of this, in terms of animal welfare, have not received the same scientific attention, as, for example udder engorgement post dry-off in dairy cows (e.g. Franchi et al., 2022). In addition to the possible pain and/or discomfort from the engorged udders, these sows may also be at a higher risk of developing mastitis during preparation for transport or during the journey. This was confirmed by the results of the survey carried out by Thodberg et al. (2020) in Denmark to collect opinions and experiences of livestock drivers transporting cull sows to slaughter. Some of the respondents of this survey expressed their concerns over the fitness for transport in sows with engorged udders. Whether being transported shortly after weaning is challenging for cull sows is, to the best of our knowledge, not known, but cannot be excluded. This constitutes a gap in knowledge.

Some conditions can make a pig unfit for transport because of reduced ability to perform an **important physiological function**, e.g. respiratory disorders can reduce exercise tolerance and capacity to deal with heat. Emaciated or weak animals may have reduced ability to obtain feed and water, are more susceptible to the combined effects of fasting and cold exposure and less able to respond to other animals and events affecting their stability (Faucitano and Raj, 2022). In addition, during transport, a diseased animal may feel ill (e.g. inappetence, thirst and fever), be more susceptible to extremes in the microclimatic conditions and might also be at increased risk of experiencing other negative affective states, such as fear (because of disorientation or reduced ability to respond to perceived danger) and distress (as discussed by Cockram and Hughes (2018) for sheep).

Although pregnancy should not in itself make a pig unfit for transport, **in late pregnancy,** there are physical and physiological changes that increase the challenges experienced during transport.

The concern for animal welfare in relation to transport of pregnant females is two-fold, and includes the pregnant female as well as the fetus/newborn:

Concerns for the welfare of the pregnant female relates to:

i) The stress and WCs associated with the different transport stages when carrying fetuses;
ii) The risk of going into labour or giving birth during transport; and
iii) The risk of abortion and health consequences thereof.

Concerns for the welfare of the fetus/newborn relates to:

i) Prenatal stress associated with being transported if the pregnant female is not slaughtered prior to farrowing;
ii) The risk of being born during transport.

Female pigs may be transported during pregnancy to move to a different barn, or transported to a farrowing paddock (for outdoor bred females). Additionally, animals may be sent to slaughter while pregnant, be it for health, welfare or management reasons, or because the farmer is unaware that the animal is pregnant (EFSA, 2017).

Across livestock species, the biology of the species in question is likely to influence the fitness for transport of pregnant females. Sows are pregnant for an average of 114 days, and give birth to a litter of semi-precocial young (Nowak et al., 2000), and modern sow breeds selected for increased litter size and productivity traits (Rutherford et al., 2013), carry between 10 and 24 piglets per gestation.

Pregnancy is associated with changes in the cardiovascular system with an increase in heart rate and important alterations of the heart rate variability as well as behavioural changes with a decreased activity level, probably due to increased metabolic demands on the sows (Marchant-Forde and Marchant-Forde, 2004). In addition, heat stress in sows can reduce the gestation length as well as the weight of the litter (Lucy and Safranski, 2017). There is no evidence from existing literature that a relationship between stage of gestation and fitness for transport has been researched in sows or gilts. The rate of fetal growth *in utero* increases cubically (Figure 3); with a period of rapid growth from mid-gestation (McPherson et al., 2004). Fetal growth leads to an increase in heat production (Zhao et al., 2020), and consequently, sows in late gestation (measured at day 99 $\pm$ 5) are more susceptible to heat stress than sows that are not pregnant or in mid-gestation (day 60 $\pm$ 10) (McConn et al., 2021), which has implications for transport in the different stages of gestation. The weight of fetuses measured by McPherson et al. (2004) were 50% greater than those studied in the 1970s by Knight et al. (1977), reflecting the selection for increased sow prolificacy and high lean growth (McPherson et al., 2004).

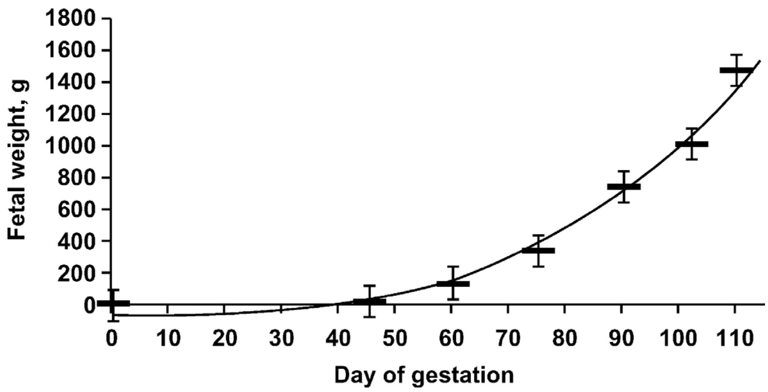


Figure 3: Increase in fetal weight over the course of gestation in sows representing cubic growth: (y = 0.00108 x^3 – 62.922, R^2 = 0.943, where y = fetal weight (g) and x = day of gestation) (McPherson et al., 2004)

Sows transported to slaughter during gestation may be fasted before and during transport. A sow off feed may be at a greater risk for ketosis during late gestation and lactation (Alsop et al., 1994), but reporting of this condition in sows is rare. The activity level of sows decreases as gestation progresses, with a marked increase in lying within the second and third trimester (Marchant-Forde and Marchant-Forde, 2004). Similarly, sow heart rate progressively increases over the course of gestation, with a pronounced increase within the second and third trimester (Marchant-Forde and Marchant-Forde, 2004), reflecting changes to cardiac output as fetal growth progresses. Consequently, sows transported in late gestation may have lower tolerance for exercise and exertion. This lower exercise tolerance, combined with increased lethargy in late gestation may make sows more resistant to moving for loading, including walking up ramps. Experience from the pig production industry practice is that handling stress and the incline of ramps should be minimised and the use of steps requiring sows to jump into, or down from trailers, avoided (Bates, 2016). There is no available data on whether transport stress can increase the risk of abortion in sows, but industry experience suggests transporting sows in early gestation (from insemination to day 45 of pregnancy) can increase the risk of pregnancy loss (Bates, 2016; Y. Seddon, personal communication).

Several existing guidelines suggest that sows should not be transported beyond 90% of pregnancy (equivalent to 103 days of gestation) (Table 14). However, no evidence to support these guidelines have been found, as, for example illustrated from Figure 3, showing the fetal growth curve of piglets.

Fetuses may be exposed to prenatal stress, that has the potential to affect them later in life (Braastad, 1998). In sows, the evidence for the effects of prenatal stress on offspring has been reviewed by Miguel-Pacheco and Seddon (2021), and there is evidence that stress experienced in the preconception as well as during gestation can influence the behaviour and physiological responses of porcine offspring. However, there is no published literature exploring the role of transport as a prenatal stressor on piglet welfare. Additionally, many of the studies exploring prenatal stress have provided stressors for a longer period of time than a single transport event may last. Therefore, it is currently unknown if and how maternal transport stress influences the welfare of piglets.

The EFSA AHAW Panel (2017) concluded that livestock fetuses in the last third of gestation have the anatomical and neurophysiological structures required to experience negative affect. However, regarding welfare of fetuses during transport, the EFSA AHAW Panel (2017) concluded, with 66–99% likelihood, that the neurophysiological situation of the livestock fetuses throughout pregnancy (e.g. inhibitory and excitatory systems) does not allow for perception of pain or other negative affect as long as the fetus is *in utero*. If this is correct, it means that welfare concerns for the fetus during transport most likely are of minor relevance. However, if this is incorrect, the fetuses might experience negative affective states while in utero. If this lesser possibility should not be precluded, pregnant females should not be transported within the last trimester.

Young pigs, particularly in the period immediately after weaning, have a reduced capacity to withstand the challenges of transport. They are at increased risk of hypothermia and hypoglycaemia. Young pigs may also be at greater risk of an infectious disease due to their underdeveloped immunity. These factors make them more susceptible to extreme conditions such as cold temperatures and long journeys without access to feed, water and rest.

Conditions affecting fitness for transport are listed in several regulations (Government of Canada, 2022; Council Regulation (EC) No 1/2005[1]), and there are several guidance documents and decision trees available to assist in the assessment of the fitness of pigs (Consortium of the Animal Transport Guides Project, 2017; WOAH, 2011, DVFA (The Danish Veterinary and Food Administration), 2019, and Factsheets from the EU Reference Center for Animal Welfare (EURCAW, 2021)). These are summarised in Table 14.

Table 14: List of conditions that can make pigs unfit for transport

General condition	Specific condition	References
Sickness/illness	Not specified further	WOAH
	Cardiovascular or respiratory disorders/laboured breathing	CATGP
	Dehydration risk and poor general status (profuse diarrhoea)	CATGP
Pathophysiological state	Weakness	WOAH
	Anaemia (pale skin, breathing quickly)	EURCAW
	Emanciation	EURCAW
	Circulatory weakness	CATGP
	Breathing difficulties	CATGP
	Fatigued/exhausted	WOAH
Injured	Not specified further	WOAH
	Serious wound, open or bleeding	CATGP, DVFA
	Disabled/infirmity	WOAH
	Severe, profuse nose bleeding	CATGP
	Profuse bleeding from the vulva	CATGP
	Significant pus discharge from the vulva	CATGP
	Swelling. Multiple abscesses and/or deformation and/or arthritis	CATGP
	Unhealed wounds after recent surgery	WOAH
	Severe blood loss	CATGP
Tail lesions	Severe tail lesions: Evidence of chewing or puncture wounds with swelling and signs of infection. Pigs appearing depressed.	EURCAW, CATGP, DVFA
	Partial or total loss of the tail with possible necrosis	EURCAW, CATGP
Ear lesions	Severe ear lesions: • Wounds involving a large part of the ear. • Exposed ear cartilage. • Inflammation/ infection deeper in the ear.	EURCAW, DVFA

General condition	Specific condition	References
	• Severe elephantiasis - the ear is so large/heavy that it limits the pig from moving normally, or from maintaining balance due to the titled head. • Acute accumulation of blood ('blood-ear').	
Shoulder sores	Open shoulder sores, if more than 5 cm in diameter	EURCAW, DVFA
Umbilical outpouchings (including true hernias)	Severe hernias: The hernia is larger than 15–20 cm (weight depending) with sores. Irrespectively of the size of the hernia sac, the pig is not fit for transport if ability to move freely is limited or the pigs appears depressed.	EURCAW, CATGP, DVFA
Skin lesions	Severe lesions risk of aggravation and major haemorrhage	CATGP
	Widespread red patches (Erysipelas)	CATGP
Eye lesion	Blind in both eyes	WOAH
	Blind	CATGP
In pain	Cannot be moved/transported without causing additional suffering	WOAH
Non-ambulatory	Animal not able to walk/move	CATGP, WOAH
Lameness	Severely impaired mobility: No weight in the affected limb(s)	EURCAW, CATGP, WOAH, DVFA
	Impaired mobility: Minimum weight on affected limb(s), severely lame	EURCAW, CATGP, DVFA
	Decidedly walking-impaired due to diagnosed or supposed fracture, dislocated joints, or other painful inflammatory conditions of the limbs	DVFA
	'Tipping' quick change on weight between affected and non-affected limb(s)	EURCAW
Prolapse	Uterine prolapse	EURCAW, CATGP
	Irreversible rectal prolapse	EURCAW, CATGP
Pregnancy	Final 10% of gestation period	EURCAW, CATGP, WOAH
Recent birth	Given birth in the previous week	EURCAW, CATGP
	Given birth in previous 48 h	WOAH
New born	Unhealed navel	EURCAW, WOAH
	Less than 3 weeks old (unless < 100 km)	EURCAW

Wording used in source material has where appropriate been modified for consistency and clarity

- CATGP: Consortium of the Animal Transport Guides Project (2017).
- WOAH: WOAH (2011).
- EURCAW: EU Reference Centre for Animal Welfare - Pigs factsheets: Fitness for transport of pigs.
- DVFA: The Danish Veterinary and Food Administration guide (2019).

3.3.3.3. Transport of animals with reduced fitness

Some guidelines and regulations list conditions that would consider pigs vulnerable, but fit for transport, as long as mitigation measures are used, e.g.

a) the pig is isolated;
b) the pig is individually loaded and unloaded without having to negotiate any ramps inside the conveyance;
c) measures are taken that are necessary to prevent the animal's suffering, injury or death during loading, confinement, transport and unloading; and
d) the animal is transported directly to the nearest place, other than an assembly centre, where care or euthanasia can be applied.

Examples of additional measures that could be used to reduce the risk of suffering by animals of reduced fitness during transport include: increased contingency planning, reducing journey duration, adjusting ventilation, increased bedding, avoiding extreme weather conditions, avoiding loading via steep ramps, loading last and unloading first, providing space to lie down, increasing monitoring frequency or providing feed, water and rest more frequently. However, the effectiveness of mitigation measures to avoid the additional suffering likely to be associated with the transport of an animal with reduced fitness is questionable. There are also differing opinions on the types of conditions that would make vulnerable pigs fit for transport, even when additional mitigation measures are used. If animals of reduced fitness are transported, they are likely to continue to experience pain and discomfort, there is a risk of deterioration of the animal during the journey, and pre-existing conditions are likely to be aggravated by transport (as described for cull sows by Thodberg et al., 2019). This constitutes a gap in knowledge.

3.4. Loading/unloading

3.4.1. Current practice

Due to the considerable physical and physiological efforts required, loading and unloading have been considered stressful steps along the pork production chain (Goumon and Faucitano, 2017). In particular, loading is preceded by potential stressful experiences, such as disruption of the social group, mixing with unfamiliar conspecifics and handling by unknown staff (Faucitano and Lambooij, 2019). Unloading follows the arrival to another farm, CP or to the slaughterhouse. The condition of pigs at this stage depends on several factors related to the previous journey, i.e. duration, stocking density, temperature and humidity inside and outside the vehicle, road and driving conditions, and depend on the category of pigs as well. Unloading should be carried out as soon as possible to avoid heat and humidity increasing in the stationary vehicle, and exposure to noxious gases (CO_2 and NH_3), unless vehicles are mechanically ventilated. Delay might expose pigs to new hazards leading to additional WCs (e.g. heat stress).

The most common device for loading and unloading pigs at the farms and CPs is the ramp, even if some trucks are equipped with a loading tail-gate lift or semi/fully hydraulic decks (McGlone et al., 2014). At the slaughterhouse, a ramp or bridge is the common device used for unloading, with the latter being more present in large slaughterhouses to avoid any difference in level from the vehicle to the dock.

The common tools for moving pigs at loading and unloading are plastic paddles, boards and flags. Codes of practice such as the 'Guide to good practices for the transport of pigs' (Consortium of the Animal Transport Guides Project, 2017) recommends avoiding electric goads for pig handling, suggesting that the use of paddles and boards are more efficient (Correa et al., 2010).

To minimise the biosecurity risks represented by the vehicle, often the ramps are located out of piggery's perimeters or outside the farm area, just at the connection with the main road. In the latter cases, pigs are moved by internal vehicles (Herskin et al., 2020b) and external trucks arrive from the outside. Irrespectively of the ramp location, the physical effort required to climb the ramp should be reduced as much as possible. Ramps no steeper than an angle of 20°, that is 36% to the horizontal, have been suggested (Council Regulation (EC) No 1/2005[1]). Moreover, where the slope is steeper than 10°, that is 18% to the horizontal, fitting systems, such as foot battens, will ensure that the animals climb or go down without risks or difficulties, effectively reducing the sharpness of the ramp. According to Dalla Costa et al. (2019), the risk of DOA increases by 4 times when the ramp slope is higher than 20° compared to a ramp slope lower than 20°.

3.4.2. Highly relevant welfare consequences

The highly relevant WCs during the loading and unloading of pigs are: handling stress, heat stress and sensory overstimulation. The selected ABMs for the assessment of these WCs are shown above in Section 3.2.2. Below, hazards, preventive and corrective/mitigating measures are described.

i) Handling stress

Most of the hazards contributing to the risk of handling stress during the loading and unloading of the animals are identical to those present during the preparation stage (i.e. inexperienced handlers, time pressure, inappropriate handling methods and devices) (Section ii). In addition, inappropriate loading facilities and inadequate loading ramps are specific hazards during the loading and unloading.

Inappropriate facilities: Poor design of loading and unloading facilities increases the difficulty of the animals to access the vehicle, increasing the risk of slipping and falling. Slippery floor surfaces may result in loss of balance. The consequent slips or falls aggravate the physical effort and lead to an increased risk of skin lesions and injuries.

- PRE: Loading and unloading areas have to be well designed with solid walls, appropriate non slippery flooring, presence of foot battens and lateral protection so that they facilitate calm and efficient handling. To ease handling, pigs should not have blind corners to negotiate, either when entering/exiting the vehicle or on the unloading ramp (Faucitano and Pedernera, 2016). As reviewed by Dalla Costa et al. (2016), A greater heart rate, balking behaviour and unloading time have been reported in pigs dealing with angles or bends of 45° to 90° compared with 0° and 30° (Warriss et al., 1991; Goumon et al., 2013; Herskin et al., 2020b).

Inadequate loading ramps: Inadequately designed ramps increase the risk of slipping, falling, bruises and additional physical stress to the animals. Keeping in mind that pigs have difficulties in ascending and descending a slope (Brown et al., 2005), ramps steeper than 20° are not recommended, as they result in greater increases in pigs' heart rate, vocalisation and backing up behaviour, increased intervention by the handler (eventually shouting and use of electric goads) and increase the time required for unloading by a factor of 3–4 (Warriss et al., 1991; Ritter et al., 2008; Goumon et al., 2013; Torrey et al., 2013a,b; Faucitano and Pedernera, 2016).

- PRE: Faucitano and Pedernera (2016)) explained that, when compared to ramps, the use of hydraulic lifts or decks reduces handling stress, increases the easiness of handling and shortens off-load time. Current guidelines do not recommend ramps steeper than 20° to be used for fixed ramps (Warriss et al., 1991) or than 25° for adjustable ramps. However, as finishers have become heavier and more difficult to move (Bertol et al., 2005; Bertol et al., 2011; Rocha et al., 2016), recent works have recommended the maximum ramp slope to be reduced to 15° (Grandin, 2012; Faucitano and Goumon, 2018).

Corrective/mitigating measures of handling stress

Corrective measures include removal of the specific person employing inappropriate handling or provision of assistance to him/her on the spot.

If an animal refuses to move, the following procedure should be applied: behave calmly, and let the animal calm down, check the animal is not sick, wounded or unfit for transport. If it is, remove it from the group and decide on the course of action (Consortium on the Animal Transport Guidelines Project, 2017).

ii) Heat stress

The hazards that can lead to heat stress during the loading and unloading of pigs are described below, together with preventive measures, and corrective or mitigating measures for the WC. More detailed information on the influence of high effective temperature on pigs can be found in Section 3.5.3.1, assessing microclimatic conditions during the journey.

High effective temperature and solar radiation: High ambient temperature and humidity may exacerbate the efforts required to climb or descend the ramp, and also the effort required to stay in the vehicle until departure. Direct solar radiation leads to an increase of temperature, worsening the environmental conditions. The application of water sprinkling in a stationary truck under warm ambient conditions resulted in the reduction of drinking behaviour in lairage, physical fatigue at slaughter (lower blood lactate levels) and drip loss in meat (Fox et al., 2014; Nannoni et al., 2014). However, water sprinkling combined with insufficient ventilation can also result in increased difference in humidity levels (up to + 7.5%) between the vehicle interior and the external environment (Fox et al., 2014), preventing efficient evaporative cooling in pigs. Further research is needed in this area before practices can be recommended.

- PRE: Avoid loading/unloading pigs during the hottest hours of the day to avoid extreme temperatures, especially when vehicles are not equipped with mechanical ventilation. When possible, the vehicle should be parked in an area that provides shade and allows for a breeze to pass through the sides, and the loading ramp should be opened (Consortium on the Animal Transport Guidelines Project, 2017). Pigs should be protected from direct sunlight during loading/unloading. If ambient temperature is above 23°C, it has been shown that water sprinkling of pigs for 5 min in the vehicle before leaving the farm and before unloading at the slaughterhouse reduced heat stress.

Delays to loading and unloading: When the temperature and humidity are high, any delay in loading or in unloading can aggravate heat stress. Moreover, in pig transport managed under US industry guidelines, and transporting finishing pigs at ~ 275–300 kg/m^2, internal temperature (quantified at pig level) in passively ventilated stationary vehicles was reported to increase up to 3–4°C in 5 min (Xiong et al., 2015). Each 1°C and 1% increase in the external ambient temperature and relative humidity was reported to increase internal vehicle temperature by 0.99°C and 0.11°C, respectively (Dewey et al., 2009). In certain compartments of a passively-ventilated truck kept stationary for 0.5 h, the temperature was found to be between at least 6 and 10°C higher than the external ambient temperature (Weschenfelder et al., 2012; Faucitano and Goumon, 2018). This has only been shown in few truck types, with certain space allowances and for certain pig categories, of which the majority were not European, and it is thus possible that the difference may be higher or lower under European conditions. Research is needed to clarify changes in temperature in stationary vehicles under European conditions.

- PRE: The stage of loading has to be organised to ensure that the vehicle starts moving as soon as possible, and, if possible, loading should be carried out at a time of day to avoid heat stress.

Physical effort: The forced climbing to the vehicle on inclined ramp demands substantial muscular exercise which most pigs are not used to. This exercise leads to an increment of respiration, body temperature, and heart rates.

- PRE: Ramps should be properly designed with ideally no greater than 15° slope.

Stocking density: Large groups of pigs collected and forced to move in a restricted passageway, like the ramp, or forced to move out from the vehicle, are very difficult to handle because of fear from narrow passageways or corridors as well as fear of novelty.

- PRE: The pigs should be moved in small groups using their natural 'following' behaviour (Grandin, 2016a,b).

Time off water: If pigs do not have access to water (or for some reason fail to obtain water) during preparation, dehydration will increase the risk of heat stress during loading.

- PRE: The provision of water before loading and after unloading can prevent the development of heat stress. Thus, pigs need to have access to water on farm until being loaded on the vehicle.

Corrective/mitigating measures for heat stress

In case of heat stress in any pig during loading/unloading, the identified animal should be removed from the area, moved to a place with shade and ventilation (fan) and provided with water. Animals can be cooled down using water sprinklers, showers, or equivalent, if the ventilation permits exchange of humidity.

iii) Sensory overstimulation

The main hazards that can lead to the sensory overstimulation at this stage of the journey are listed below.

Sound/noise: Unfamiliar noises from the vehicle, or shouts from the handlers can increase the risk of sensory overstimulation.

- PRE: Any unnecessary noise should be avoided and, a calm loading area should be selected.

Lighting: Sudden change or inadequate lighting (high contrast with bright and shaded areas) during loading/unloading may induce fear and slow down handling.

- PRE: A strong contrast of light should be avoided as well as direct sunlight in the eyes of the animals.

Corrective/mitigating measures of sensory overstimulation

If pigs experience sensory overstimulation during loading/unloading, the environment should be checked to identify the sources and remove them (i.e. switch off the machinery creating the unfamiliar noise, modifying the lights).

3.5. Transit stage

3.5.1. Current practice

After loading onto the vehicle, the animals are transported to another farm or to the slaughterhouse, sometimes passing CPs or assembly centres on the way. Often the term journey is used to encompass all management and actions taken from the place of departure to the destination including any unloading, accommodation and loading that occurs at intermediate points in the journey. However, in order to be able to separate the assessments of animal welfare during the part of the transport practice where the animals are being moved from breaks in the movement (e.g. during stays in CPs), in this Scientific Opinion, the transit excludes loading/unloading and journey breaks, and starts when the ramp has been closed and ends when the first animal unloads or the vehicle parks for a break in the journey aimed to rest, feed or water the animals (as defined in Section 1.2).

There is a diverse range of vehicles used to transport pigs, of which many are trucks with multiple decks (see Figure 4).

Figure 4: (A) Three-deck pig truck collecting cull sows from a pick-up vehicle in Denmark. Source: Thodberg et al., 2019; (B) Four-deck truck with 5-deck trailer transporting weaners. Photo: Aarhus University

3.5.2. Highly relevant welfare consequences

Welfare of pigs during the transit stage of transport depends on several factors such as journey duration, space allowance, ambient conditions (temperature, humidity, vibrations, and noise) vehicle design and driving conditions (Schwartzkopf-Genswein et al., 2012; Faucitano, 2018).

The WCs selected as highly relevant during the transit stage of pig transport are: group stress, heat stress, injuries, motion stress and sensory overstimulation, prolonged hunger, prolonged thirst, resting problems and restriction of movement. The ABMs used to assess each WC have been defined above. The hazards leading to the WCs are identified below as well as preventive measures and mitigating or corrective measures.

i) Group stress and injuries

Group stress is a highly relevant WC for pigs during the transit stage. Injuries are often the physical outcome of group stress in pigs, and therefore these two WCs are combined here. The main hazard contributing to group stress and injuries is the mixing of pigs that are not familiar to each other.

Mixing unfamiliar pigs: It takes several days after mixing for pigs to establish a new social hierarchy. This means that any pre-journey mixing increases the risk of aggression and injuries as a result of fighting taking place during the transit stage.

- PRE: To prevent this hazard, pigs that are not familiar with each other should not be mixed at any stage during transport. In order to allow this to happen, compartment size should be adjusted to on-farm group size.

Corrective/mitigating measure of group stress

If pigs are mixed, the consequences during the transit stage are difficult to mitigate, as it is natural behaviour of newly mixed pigs to fight. However, the level of group stress during the transit stage may possibly be mitigated by avoiding competition for resources such as water and lying places, and to avoid exposing the pigs to other hazards that may induce fighting.

ii) Heat stress

The hazards contributing to the risk of heat stress during the transit stage are broadly similar to those in the loading/unloading stages; namely high effective temperature and solar radiation, physical effort, stocking density and time off water. In addition, the ventilation rate and high temperatures inside vehicles contribute to increase the risk and severity of heat stress. The main hazards contributing to heat stress together with their preventive measures and mitigative and corrective measures of the WC are described below. More detailed information on the microclimatic conditions recommended for the transit stage is included in Section 3.5.3.1 assessing thresholds for microclimatic conditions.

High effective temperature: High effective temperature inside the vehicle (dry temperature combined with high humidity) is the major hazard for heat stress. In vehicles equipped with natural as well as mechanical ventilation, the major determinant of the microclimatic conditions inside, is the outdoor climatic conditions. The temperature and humidity outside the vehicle dictate the temperature and humidity of the air coming into the vehicle via air vents. In the absence of air conditioning, the effective temperature in the vehicle can never be lower than that outside. Solar radiation can also play a significant role by heating the vehicle over and above the effective temperatures seen outside.

- PRE: To prevent this hazard, animals should be transported in their TCZ, as explained below in Section 3.5.3.1, where the upper threshold of the comfort zone and the upper threshold of the thermoneutral zone (TNZ) (the upper critical temperature, UCT) are identified as the basis of a quantitative recommendation on microclimatic conditions during transport of different categories of pigs. If outside temperatures are higher than the TCZ, the hazard can to some extent be prevented by avoid transporting animals during the hottest hours of the day.

Solar radiation: Solar radiation on the roof and walls of the vehicle causes the interior of the vehicle to heat up.

- PRE: In construction of vehicles, radiation-reflecting material should be considered to reduce the risk of heat stress.

Low ventilation rate: Ventilation replaces the air in the vehicle with air from outside the vehicle.

- PRE: To reduce the risk of high effective temperatures inside the vehicle, appropriate ventilation should be ensured. This will remove metabolic heat from the animals and also help to avoid concentration of gases and fumes, thereby also reducing the risk of sensory overstimulation.

Stocking density: Lowering space allowance increases the number of pigs that can be loaded onto a vehicle and the amount of metabolic heat and moisture that they produce will increase.

PRE: Increasing space allowance can help to reduce the risk of heat stress, by allowing the animals room to lie on their side without touching each other. As described in detail in Section 3.5.3.2, whether increasing the space allowance as such can contribute significantly to the microclimatic conditions inside the vehicle is uncertain.

Time off water: Described in Section 3.4.2 [ii heat stress].

Corrective/mitigating measure of heat stress

When animals show signs of heat stress, they should be unloaded immediately, moved to a place with shade and ventilation (fan) and provided with water. Animals can be cooled down using water sprinklers, showers or equivalent, if the ventilation permits exchange of humidity.

If unloading cannot be done immediately, it is recommended to complete the journey as soon as possible, increasing ventilation if possible, to provide convective air cooling. Avoid stopping the vehicle when ventilation is restricted.

iii) Motion stress and sensory overstimulation

The two WCs, motion stress and sensory overstimulation share mediating biological mechanisms, ABMs and to some extent also hazards. They are, thus, treated in combination during the transit stage of transport. The main hazards leading to these WC in pigs during the transit stage are listed below, and the ABMs have been described in Section 3.2.2.

As reviewed by Valadez Noriega and Miranda de la Lama (2020), during transport, animals are exposed to vertical, lateral and horizontal vibrations. Unpaved roads or roads with strong wind currents transmit a more significant amount of vibrations. An animal's sensitivity increases after long standing periods (Gebresenbet et al., 2011), causing fatigue and displacement of their centre of gravity, which may lead to falls and injuries (Bulitta, 2015). Transport motion research has focused on road transport and there is, thus, limited research on for example air transport motion, even though it has potential to stimulate the vestibular system and produce body instability, both precursors of motion sickness (Santurtun and Phillips, 2015). The vestibular system detects motion and gravity and initiates movements to maintain balance and orientation. Further research is needed to investigate physiological and behavioural responses to determine responses to this condition, leading to a better understanding of how motion sickness could affect livestock during transport (Santurtun and Phillips, 2015).

During transport, animals experience stress and/or fatigue due to the forces exerted as a result of acceleration, braking, stopping, cornering, gear changing, vibrations and uneven road surface. Vibration is the movement of a body about its reference position, and occurs because of an excitation force that causes motion. Vibration has been shown to alter animal behaviour and induce physiological changes as well as to cause effects at the cellular and molecular levels. For these reasons, vibrations have a considerable potential to alter animal welfare status (Reynolds et al., 2019). Vibratory movement has a direction (generally in three planes) (Figure 5), a magnitude (how far) and a velocity (how quickly – what rate).

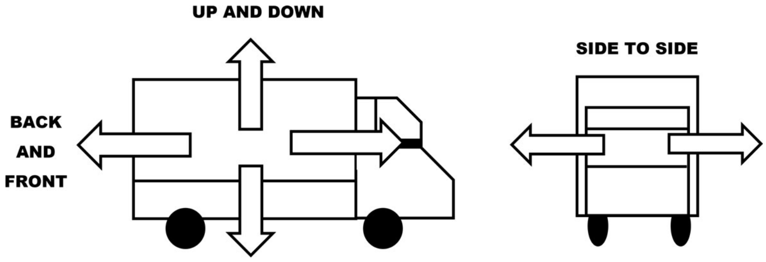


Figure 5: Schematic drawing showing the three planes of vibratory movements animals are exposed to during transport by road (adapted from Humane Slaughter Association, 2022)

Rolling and pitching of vehicle: While the vehicle is moving, all pigs are to some extent exposed to motion stress, which may lead to motion sickness in this animal species. The stress is increased during driving events, such as acceleration, braking and turns. Rural roads are a mixture of unsurfaced, paved and surfaced roads. The former two increase the transmission of vibrations to the animals compared to larger roads and, when waterlogged, can cause the vehicle to lose stability, and the animals to lose their balance.

- PRE: Among the preventive measures for this hazard are planning journeys on motorways, with vehicles equipped with good suspension and driven by experienced and skilled drivers. In addition, vehicle vibration can be reduced through a suspension system which, in the case of freight trucks, can be either leaf spring or air suspension. Both suspension systems improve vehicle contact with the road surface and indirectly reduce vehicle vibration (Dalla Costa et al., 2017).

Rough driving: Rough driving, which includes high acceleration and forceful braking, may cause postural instability, leading to toppling, sliding and excessive corrective muscular action, resulting in bruising, muscular fatigue, fear and general injuries to animals during transport (Driessen et al., 2020a,b). The proportion of pigs standing or lying associated with an increase or decrease in acceleration was examined by Peeters et al. (2008) who studied the combined effect of driver and driving style on the behaviour of pigs and other physiological indicators during a short journey. In addition, the effect of differing accelerations (longitudinal, lateral and vertical) of the trailer on these variables was studied. Increasing acceleration resulted in increased 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. Randall et al. (1996) recommended a good air suspension on all axles of the vehicle to reduce vibrations. Driessen et al. (2008) examined the effect of vibration on cardiac activity and lying behaviour in 90 pigs which were vibrated in the vertical direction in a transport simulator with a frequency of 8 Hz and an acceleration of 3 m/s^2. The effect of vibration increased heart rate. More recently, Morris et al. (2021) collected and interpreted three-axis acceleration, temperature and relative humidity data from six locations within commercial transport trailers transporting finisher pigs. Based on the data collected, the greatest vibrations (both horizontal and vertical) occurred in the bottom rear compartment which may potentially expose pigs to uncomfortable transport experience that could result in discomfort or fatigue.

- PRE: Adequate driving style should be ensured to limit acceleration, braking, and cornering which affect the ability of the animals to maintain postural stability. The route should be well planned with a view to avoiding rough and winding roads which may exacerbate WCs due to motion stress.

Excessive stimuli (lights, odours, noise, etc.): During a journey, animals are exposed to numerous stimuli, including noise originated from traffic or from mechanical ventilators. According to Talling et al. (1998), the sound level experienced by pigs during transport (88 to 96 dB) is almost as high as what they are exposed to in the peri-mortem area at the slaughterhouse (89–97 dB). Sounds higher than 70 dB are deleterious to pig welfare since they induce an increase in heart rate, interpreted as fear, making the animals more fearful and difficult to move (Goumon and Faucitano, 2017). In addition, improper design of the vehicle or of compartments holding animals may lead to the risk of introducing exhaust fumes into the space destined for the animals. Improper ventilation without the removal of noxious gas (such as NH_3) produced by the animals and their excreta, leads to overexposure followed by clear signs such as watering eyes, nasal discharge and coughing, retching and ocular/vision disorders. In addition, sudden or inadequate lighting (high contrast with bright and shaded areas) during the journey will have a negative effect on pigs and may lead to stress and fear.

- PRE: The use of an adequate vehicle should reduce hazards such as excessive noise as well as the possible introduction of exhaust fumes into the space destined to the animals.

Space allowance and conditions inside the vehicle: The maintenance of balance in transit involves great physical effort (Terlouw et al., 2008). Therefore, during the journey, pigs should have enough space, and of adequate quality in terms of surface texture, dryness and hygiene, to lie down, stand up, and turn around without hindrance (Velarde et al., 2021).

- PRE: Pigs should have enough space and of adequate quality in terms of surface texture, dryness and hygiene to lie down and get up again.

Pigs that have eaten a large meal before start of a journey: Motion sickness has been described in several species, including pigs (Randall and Bradshaw, 1998; Santurtun and Phillips, 2015). Pre-transport fasting has been suggested to decrease the likelihood of motion sickness (Randall, 1992; Bradshaw et al., 1996a). However, the scientific evidence for an optimal fasting time regarding motion sickness is sparse. Warriss et al. (1998) reviewed the available literature, and concluded that the minimal interval is unclear, but suggested that, at least on vehicles showing poor vibrational characteristics or when transported on rough roads, on-farm fasting of ~ 12 h may be preferable for finishers in terms of in-transit mortality. The mortality rate of transported finisher pigs that have been fasted 8–18 h before loading has been reported to be significantly lower than that of pigs loaded on a full stomach (Warriss and Brown, 1994; Guàrdia et al., 1996). According to Averós et al. (2008), the mortality risk of non-fasted pigs increases with transport up to 8 h.

The studies mentioned above focused on in-transit mortality as the outcome. From a production point of view, pig mortality is unwanted, and it is likely that pigs dying in transit experience negative WCs during their last hours alive. However, even though periods of fasting may be beneficial in terms of mortality and associated WCs, fasting pigs may experience other WCs due to the hours off-feed, such as hunger, group stress (as reviewed by Faucitano, 2018) and handling stress (Dalla Costa et al., 2016). According to Warriss et al. (1998), it is likely that pigs are feeling very hungry at 12 h after their last meal. Thus, the decision on pre-transport fasting is likely a compromise between several concerns related to animal welfare.

Importantly, the available data on effects of pre-transport fasting on behaviour and welfare of pigs are all from studies of finishers. The relationship between hours off feed and the risk of developing motion sickness (and other WCs such as prolonged hunger or group stress associated with the fasting), in cull sows (where a significant proportion is producing milk at the time of slaughter and thus used to a high feeding level (Thodberg et al., 2019)) is not known. This constitutes a gap in knowledge.

For pigs transported for further fattening or breeding, fasting can be beneficial to avoid motion sickness, but concerns about hygiene at slaughter are not relevant. For these categories of pigs no studies have identified pros and cons of pre-journey fasting, examined effects of fasting duration or established guidelines, for example taking into account different types of feed (wet feed vs dry feed fed from feed stations), or potential post-transport consequences of the fasting in terms of health impairment (e.g. the development of gastric ulcers). This constitutes a gap in knowledge.

- PRE: In order for pigs not to be at risk of developing motion sickness caused by full stomachs, pigs should not be able to eat a full meal shortly before journey initiation. See Sections 3.3.2 [iv prolonged hunger] in preparation and Section 3.5.2 [iv prolonged hunger] during the transit stage for further assessment of the use of pre-transport fasting in pigs.

Corrective/mitigating measures of motion stress and sensory overstimulation

If the severity of the motion stress and sensory stress is too high on the animals, the driver can stop the vehicle, unload the animals and give them some rest. Otherwise, the best option would be to finish the journey as soon as possible.

iv) Prolonged hunger

Prolonged hunger is regarded as a highly relevant WC during the transit stage. The prevalence is expected to be very high, as pigs – especially animals sent for slaughter – most often have been fasted before the initiation of the journey. The severity of hunger will develop further during the transit stage. The duration of hunger depends on journey duration and availability of feed in transit, and severity is expected to increase with increasing duration, as the need for feed becomes problematic for the animals. Prolonged hunger may lead to frustration, exhaustion and a weakened condition. The main hazard leading to prolonged hunger during the transit stage is time off-feed. Additional information on the effect of duration of food deprivation on hunger of pigs can be found in the assessment of journey duration (Section 3.5.3.3).

Time off feed: Feed deprivation can result in prolonged hunger.

- PRE: To prevent prolonged hunger, fasting duration at farm has to be appropriate for the journey duration. See Section 3.5.3.3 for recommendations on journey time for the different pig categories.
- Careful planning of the transport time, scheduling and prioritising the slaughter of the animals (if destined for slaughter) should be done to avoid prolonged periods with food withdrawn.

Corrective/mitigating measures of prolonged hunger

To mitigate the WCs of prolonged hunger, the journey should be terminated as soon as possible. Upon arrival at a slaughterhouse, pigs showing signs of prolonged hunger should be prioritised for slaughtering or fed in lairage. Feeding the pigs in the moving vehicle is not recommended as they will be at risk of developing motion sickness, and due to increased risk of aggression.

v) Prolonged thirst

Prolonged thirst is regarded as a highly relevant WC during the transit stage. The prevalence may be high, if water is not provided to the animals, or if they for some reason (e.g. due to lack of familiarity with drinking devices, neophobia or fear of other animals) are not able to obtain enough water. Depending on factors such as time off water before journey start and/or microclimatic conditions, pigs may not be thirsty during the initial phase of the journey, but thirst will develop over time, if they are not drinking as much as they need. The duration of prolonged thirst depends on time off water, and severity is expected to increase with increasing journey duration and heat, as the need for water becomes problematic for the animals. Prolonged thirst may lead to dehydration, discomfort and suffering. Main hazards for this WC are listed below, and additional information is included in the quantitative assessment of the journey duration (Section 3.5.3.3).

Time off water: If no water is accessible in the vehicle compartments, animals experience water deprivation, in the period from when they leave the last water source and until they again have access to water.

- PRE: To prevent this hazard, pigs need to have access to water on farm until being loaded on the vehicle. Animals have to be prepared carefully to be transported, i.e. in reference to fluid balance. There is no demonstration of advantage in water deprivation prior to transport. As examined in Section 3.5.3.3, the evidence for the welfare benefits of providing pigs with water during the transit stage is currently limited, and further research is needed in this area to develop effective preventive measures.

Limited space allowance affecting possibility to thermoregulate: During the journey, insufficient space for all pigs to lay down in lateral recumbency will deny them the possibility for thermoregulation and might exacerbate heat stress and thirst.

- PRE: Sufficient space allowance should be provided for the pigs to lay down during transport. Additional quantitative information on space allowances can be found in Section 3.5.3.2.

Inadequate/not working drinkers: Even when transported under condition where water is provided to pigs during the transit stage, dehydration may occur if the drinking devices are not designed and positioned in an appropriate way considering the category and the size of pigs and if they are not available to all pigs held in the compartment. On a vehicle drinkers maintain the water cleaner than troughs or buckets.

- PRE: The driver must ensure to store (and/or replace) sufficient water in the vehicle's tanks and to check the function of the water supply system on the decks. Drinkers should be readily available at the appropriate angle and height for the animals.

Reduced intake of water: Only few studies have examined the intake of water during pig transport. If pigs drink less than they need during a journey, they might develop prolonged thirst even though drinkers in principle can be in place. See Section 3.5.3.3 for an examination of this hazard in relation to journey duration.

- PRE: If pigs drink less water than required during transit, this hazard cannot be fully prevented during the journey phase, not even by giving access to drinkers on vehicles. The only preventive measure, then, is to provide free access to water before loading, and to limit journey duration, so that prolonged thirst will not develop. If journey breaks are involved, pigs should be watered there.

Reduced accessibility of water: As discussed further in Section 3.5.3.3, reduced accessibility of the water may be one hazard for the development of prolonged thirst during the transit stage, even in vehicles equipped with drinking nipples.

- PRE: Only few studies have examined the intake of water during pig transport. Among factors of importance for this hazard are design of drinkers (height, position, angle, type), lack of familiarity, lack of space to manoeuvre inside vehicles and effects of the behaviour of the other animals. Currently, no studies have documented drinking systems and management thereof to prevent the hazard of reduced accessibility. This constitutes a gap in knowledge.

High effective temperature in vehicle: Too high effective temperature may have a cumulative effect on time for water deprivation.

- PRE: To prevent this hazard, temperatures inside the vehicle should be kept within the TCZ, as described in detail in quantitative examination of microclimatic conditions (Section 3.5.3.1).

Corrective/mitigating measures of prolonged thirst

In the case that signs of prolonged thirst are observed during the transit stage, the vehicle should be stopped, and all pigs given the opportunity to drink water, providing enough time for this, and sufficient quantities of drinkers for the number of animals in the group. At CPs, pigs must be watered and fed, to recover from thirst and to have enough energy to continue the journey.

vi) Resting problems

Resting problems are regarded as a highly relevant WC during the transit stage. The prevalence is at least moderate, as resting problems may affect a large proportion of animals in a moving vehicle, depending on factors such as the driving conditions and the space allowance. Duration of resting problems depends on the journey duration, and severity is expected to increase with increasing duration, as the lack of resting becomes problematic for the animals. Resting problems may eventually lead to fatigue. Below, the main hazards are identified and preventive, corrective and mitigating measures suggested. A more thorough assessment of resting problems during the transit stage can be found in Section 3.5.3.3.

Vehicle motion and poor driving conditions: The movement of the vehicle, and especially when driving is not done in a calm and focused way, and when road conditions are of lower quality, pigs have to make continuous postural adjustment to acceleration changes, maintain their balance and to avoid falling (see above and in Section 3.5.3.3 for examination of motion stress).

- PRE: A series of preventive actions (see above for the examination of motion stress as well as in Section 3.5.3.3) can be initiated to lower vehicle motion and thereby to reduce resting problems.

Insufficient horizontal space (space allowance): When the stocking density is too high, the animals do not have the space to lie down and get up again, increasing the risk of resting problems during the transit stage.

- PRE: Pigs should be provided with enough space to allow them to rest, as described in detailed in quantitative examination of the space requirements (Section 3.5.3.2).

Unsuitable floor and inadequate bedding: Poorly maintained or poorly designed corrugated patterns of flooring do not allow animals to comfortably maintain balance during the transit stage, predisposing them to slipping, falling and constant changes of position. Anti-slip materials should be used. In addition, without adequate bedding (type and/or quality and/or quantity) animals will be less motivated to rest lying down during journeys (Goumon et al., 2013) and may be exposed to slips, falls, fatigue and weakness.

- PRE: Sufficient bedding (in terms of quality and quantity) should be provided for the journey, made of adequate materials such as sawdust.

Insufficient vertical space: A deck height forcing animals to adopt abnormal positions during the transit stage is problematic. In addition, low deck height can be associated with (1) reduced ventilation; (2) lack of ability to move around; and (3) lack of space for natural movements, and should be prevented in order to avoid WCs such as heat stress and restriction of movement. Information on the minimum height of the decks is provided in Section 3.5.3.2 where a quantitative assessment is done for the vertical space required by pigs during transport.

- PRE: In order to prevent resting problems induced by insufficient vertical space, the deck height should allow animals room to move around and for natural movements. See Section 3.5.3.2 for a quantitative assessment for the vertical space required by pigs during the journey.

Mixing unfamiliar animals: Mixing unfamiliar pigs exacerbates aggressiveness and can therefore increase the risk that pigs are prevented from resting during journeys.

- PRE: Making sure that all pigs in a vehicle compartment have been together for at least some days before transport, reduces the risk of aggressive interactions and fighting during the transit stage.

Corrective/mitigating measures of resting problems

In extreme situations where severe resting problems have been identified, pigs can be offloaded and allowed to rest. Otherwise, the journey should be finalised as soon as possible and upon arrival animals should be given enough space and calm environment to rest.

vii) Restriction of movement

The main hazard leading to the restriction of movement of pigs during the transit stage is the provision of insufficient space for the animals – horizontal as well as vertical space. This topic is covered in detail in Section 3.5.3.2, where detailed research is compiled to provide quantitative recommendations of space allowance during transport.

Corrective/mitigating measures of restriction of movement

In case of restriction of movement is suspected during the transit stage, the journey should be finalised as soon as possible. Upon arrival, animals should be unloaded with no delays and provided sufficient space to rest.

3.5.3. Quantitative examination of thresholds to protect the welfare of pigs during the transit stage: microclimatic conditions, space allowance and journey time

3.5.3.1. Threshold of microclimatic conditions

A) Introduction – pig biology and consequences of selection for productivity

Pigs are special among mammals as most of their sweat glands are non-functional. In addition, pigs have relatively small lungs, thereby reducing their ability to dissipate heat by panting (D'Allaire et al., 1996) and characteristically carry a thick subcutaneous adipose tissue layer, which impedes radiant heat loss. Taken together, this means that pigs have difficulty dissipating heat and may experience heat stress, especially at combinations of high ambient temperature and high humidity (Ross et al., 2015).

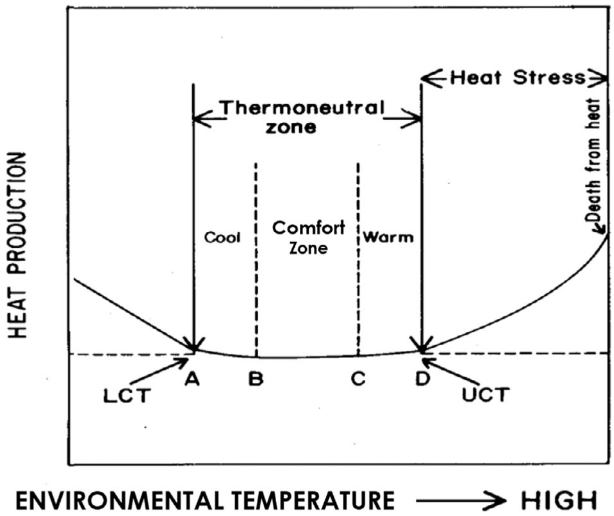
Heat stress is not only a problem for pigs during transport, but also a welfare concern under production conditions, leading to significant challenges to productivity, especially in tropical regions of the world but also during periods of hot weather in Europe (Baumgard and Rhoads, 2013).

Larger pigs, especially sows, are known to be more vulnerable to heat stress than smaller individuals. These differences are caused by their large body size, low surface area: body weight ratio, higher energy intake relative to maintenance requirement (in lactating sows), and higher subcutaneous fat tissues (Renaudeau et al., 2012). For example, body heat production increases with body weight (+2% for each 5 kg increment), while heat dissipation rate decreases (Brown-Brandl et al., 2004; Renaudeau et al., 2011). In addition, animals undergoing high metabolic activity, and especially in combination with high feeding level – as for example highly pregnant or lactating sows – are typically more susceptible to heat stress than animals of lower metabolic activity (Gourdine et al., 2021). This means that the reproductive status of sows affects their response to heat stress, and that sows that produce milk likely are more vulnerable than dry sows. In terms of transport, sows can be culled at all stages of the reproductive cycle, but considerable proportions of sows have been reported to be sent to slaughter just after weaning (when still producing milk) (Fogsgaard et al., 2018).

As reviewed by Gourdine et al. (2021) and Mayorga et al. (2019), there is growing evidence that genetic selection has reduced pigs' ability to cope with heat stress, due to an increase of metabolic heat production with the improvement in reproductive traits and lean tissue growth rate, at the expense of adaptive capacities. In a review of the potential for heat stress in future livestock production, Mutua et al. (2020) stated that the highly prolific modern genetic pig lines produce almost 20% more heat than the animals produced only a few decades ago.

B) Background

Thermoregulation is the physiological process allowing the balance between heat production and heat loss mechanisms. The approach taken in this Scientific Opinion to recommend microclimatic conditions during pig transport is based on the thermoregulatory concepts and model as described by EFSA (2004), and originally formulated by Mount (1974). The figure covers a range of environmental temperatures from cold to very hot. Since the selection of highly relevant WCs was not done per animal category (cold stress is likely more relevant for pigs close to weaning than for older categories), but per animal species, cold stress was not chosen as a highly relevant WC for the average pig. Thus, this assessment of thresholds for microclimatic conditions focusses on temperatures higher than B as indicated on Figure 6.



LCT/A: Lower critical temperature (LCT), UCT/D: Upper critical temperature; B: Lower limit of thermal comfort zone; C: Upper limit of thermal comfort zone.

Figure 6: Schematic representation of thermal zones as a function of the environmental temperature (Adapted from EFSA, 2004)

The following three concepts from the figure need to be introduced:

Thermoneutral zone: As reviewed by Bracke et al. (2020), the TNZ covers the range of environmental temperatures within which metabolic rate and heat production are constant and independent of the ambient temperature. The zone is limited by the lower critical temperature (LCT) (marked as A in Figure 6) and the UCT (marked as D in Figure 6). Many factors influence the TNZ of an individual animal including the size, body condition score, breed, level of nutrition, agitation level, and environmental factors such as humidity, radiation, heat loss to the floor, air velocity around the animal, but also motor activity (e.g. maintaining balance during transport) (Bracke et al., 2020).

Thermal comfort zone: According to Silanikove (2000) subdivision of the TNZ into a zone of thermal well-being is the most suitable way to describe the relation between an animal and its environment from the viewpoint of animal welfare. Based on studies in humans (e.g. Schlader et al., 2011), Kingma et al. (2014) described the TCZ as defined in terms of perception, qualifying as the state of mind that expresses satisfaction with the thermal environment. Translated into animal welfare, Silanikove described the TCZ (denoted comfort zone in Figure 6) as the environmental temperature interval, where the energetic and physiological efforts of thermoregulation are minimal, and the animal is in the preferred or chosen thermal environment. In the figure above, the upper limit of the TCZ is marked by C, where an animal will activate evaporative physiological thermoregulation processes, and may start to display thermoregulatory behaviour. The TCZ is sometimes called the safe zone as it is referred in EFSA Scientific Opinion to be published in 2022 on the welfare of animals in containers during transport (EFSA AHAW Panel, 2022c)

Upper critical Temperature (UCT): As outlined in EFSA (2004), there are several definitions of UCT. The UCT describes the point above which an animal must significantly increase the use of physiological mechanisms to prevent a rise in body temperature above normal. For example, evaporative heat loss increases and metabolic rate increases (Silanikove, 2000). As described by Norris and Kunz (2012), heat is transferred by four mechanisms: radiation (from a hot object to a cooler object via electromagnetic waves), conduction (between two solid objects in contact with one another), convection (through the movement of a gas or liquid) and evaporation (conversion of water from the liquid to gas phase). In the TNZ, evaporation is per definition kept to a minimum, whereas increased evaporative heat loss through the skin and/or respiratory tract occurs when the organism is challenged with higher ambient temperatures. At high ambient temperatures, heat transfer by conductive, convective and radiant changes are less effective, because of the reduction of the required minimal thermal gradient between skin and air temperature (Renaudeau et al., 2012).

According to the definition of WCs published by EFSA AHAW Panel, (2022a), the term 'heat stress' is defined as: 'A situation, where an animal experiences stress and/or negative affective state(s) such as discomfort and/or distress when exposed to a high effective temperature'. This definition differs to some extent from other proposed definitions of heat stress, focusing on lack of ability to cope or on performance loss.

The scientific literature underpinning the model shown in Figure 6 is based on studies involving a certain level of feed intake under stable or resting conditions. As reviewed by Bracke et al. (2020), care should, thus, be taken when extrapolating findings obtained from experiments in conventional barns to transport conditions. During transport, pigs are often exposed to factors that may act as stressors and/or limit their possibility to thermoregulate, as they would have done in non-transported control conditions. In contrast to the conditions provided to the pigs under basic thermoregulatory studies, transport often includes deprivation of feed and water, exposure to vibration and motion forces, low space allowances and highly variable ventilation rates. Consequently, if a negative impact on animal welfare from the microclimatic conditions during journeys is to be fully prevented, animals should be transported in their TCZ. This means that the WC, heat stress, defined by the accompanying stress and/or negative affective states, may start when an animal is no longer in the TCZ, and the risk and severity of heat stress, is likely high when animals reach UCT. Once this point is reached, the rate of evaporative heat loss starts to increase exponentially, meaning that signs of heat stress, in pigs mainly seen as panting and attempts to lie laterally, increase steeply in an effort to stop the rise in core body temperature above normal.

The warm zone in Figure 6, also sometimes called the alert zone (EFSA AHAW Panel, 2022c), between temperatures C and D is not as such included in the TCZ. However, even though heat stress cannot be fully excluded when animas are exposed to conditions as between C–D, the risk and the severity of heat stress is likely not high in this interval. This approach is based on the definition of the animal WC heat stress, addressing a situation where an animal experiences stress and/or negative affective states such as discomfort and/or distress.

C) Heat stress and animal welfare during transport of pigs

As reviewed by Rashamol et al. (2019), Bjerg et al. (2020), and de Castro Júnior and Silva (2021), not only the ambient temperature, but also other environmental conditions influence heat load placed on animals. Examples of these are: relative humidity (RH), thermal radiation, solar radiation including long- and short-wave radiation, temperature of surrounding surfaces, the heat and moisture generated by the animals, the heat loss from the vehicle, vertical space, placement of compartment partitions along the longitudinal axis of the vehicle, the vehicle type, the type of ventilation shutters, wind speed, the opportunity for pigs to moisten their skin and many more. These will all influence the microclimatic conditions experienced by pigs and should, in theory, all be taken into account when microclimatic conditions of pigs during transport are evaluated. However, due to the complexity of such tasks, as well as the strong evidence for the effect of humidity on heat stress, at least the combined effects of temperature and humidity should be taken into account when animal welfare during transport is evaluated.

The water vapour content of air is important because it impacts the rate of evaporative heat loss through the skin and respiratory tract (Bohmanova et al., 2007). When the ambient temperature is above the animal's TCZ, a high level of humidity in the air will reduce evaporative heat loss and therefore result in increased risk of heat stress. In this case, the routes of conduction, convection and radiation for heat exchange are reduced, and the only remaining route of heat loss is through evaporative routes, which require a vapour pressure gradient and thus dictates that relative humidity is a major factor controlling rate of evaporative loss.

Generally, air water vapour content is assessed by RH, which is a measure of the percentage saturation of the air with water vapour at a specific temperature in relation to the maximum water vapour that the air could potentially contain at that temperature. However, RH is temperature dependent and thus the same RH at different temperatures may equate to very different water vapour contents. Therefore, although sensors recording temperature have been used in road transport of pigs in the past, it would be a significant refinement to use improved sensors that take into account humidity effects.

In the context of animal transport, ventilation functions to replace the metabolic heat and moisture produced by the animals inside the vehicle with air of a certain humidity and temperature from outside the vehicle. Ventilation also serves to mix and redistribute internal air to attempt to make the internal thermal micro-environment more homogeneous. In addition, concentrations of different gases (O_2, CO_2, NH_3) can be modulated. The effect on individual animals depends on the rate of air change and the flow around the bodies of the animals. In this way, the temperature and humidity (and all other microclimatic conditions) in the vehicle can, in theory, be maintained only slightly elevated compared to the level of those outside the vehicle, but only if ventilation is very efficient.

However, in a passively ventilated vehicle, air flow over the surface of the moving vehicle results in a pressure gradient in which there is lower pressure towards the front sides of the vehicle than at the rear sides and tail. There may be higher pressure on the front (forward face or headboard). The net effect is that in a passively ventilated configuration, air movement will tend to involve entry of air towards the rear, forward movement of air towards the front of the vehicle and exit of air at the front sides of the structure (Figure 7).

Figure 7: Predominant patterns of air flow (black arrows) in a moving passively ventilated vehicle. Red areas indicate where air heated by the animals accumulates and blue areas show colder spots. Photo: Marianne Kaiser, Aarhus University

For all passively ventilated vehicles, when the vehicle is stationary (e.g. during mandatory driver breaks), there is no driving force for ventilation other than buoyancy or free convection or external factors, such as cross winds. The problems when stationary will be exacerbated in vehicles operating with restricted air inlets with minimal gaps for air to enter, exit and circulate within the load.

Even vehicles fitted with fans to aid ventilation often have the airflow dictated by two principles. The stack effect causes heated air to rise and colder air to descend and is the dominant means in stationary vehicles. When moving, the stack effect continues to operate, particularly in areas of the load with low ventilation, but is overlaid by the air flows which operate around and within a vehicle in motion. Both of these drivers of air flow may be influenced by external factors, such as wind. In the type of transport vehicle used in the EU, the pressure field around the vehicle drives the passive ventilation, and air will tend to enter towards the rear of the vehicle and exit towards the front side of the load. The presence of the sides on the vehicle limits air entry and exit along the sides of the vehicle and the route for air flow will be determined by the location of any openings in the structure. This results in uneven distribution of thermal conditions within the load with hot-spots (red) and cold-spots (blue) indicated in Figure 7 above.

As discussed by Mitchell and Kettlewell (2008), there is a ventilation rate (by mechanical or passive ventilation), for a certain range of environmental temperatures, that, in theory, reduces the effective temperature within the vehicle to the same level as that outside the vehicle. This rate will depend on many factors, such as the temperature and humidity of the air coming into the vehicle, the heat and moisture and heat generated by the animals, solar radiation and heat loss from the vehicle. To the best of our knowledge, this ventilation rate is unknown for pig transport, as the relevant studies have not been found.

Calculations of total heat production of finisher pigs and sows are around 2.0–2.5 W/kg for finisher pigs (Brown-Brandl et al., 2004) and 1.89 W/kg for breeding sows (Stinn and Xin, 2014), although the total heat production will change depending on temperature, stage of fasting and activity of the animals. Mitchell and Kettlewell (2008) measured the heat production of 100-kg finishing pigs during transport at a stocking density of 0.42 m^2/pig. The heat output varied by stage of the journey, being highest after loading at 3.4 W/kg, falling to 1.5 W/kg following 3 h of transport, and rising back to 3.3 W/kg during a 2-h truck stationary period, reducing to 2.0 W/kg as the truck continued on the journey.

The production of water vapour followed a similar pattern (Mitchell and Kettlewell, 2008), with the production level during transport, while the vehicle was moving, being 0.0003 g/s per kg. Given the change in activity and the output of metabolic heat and water vapour, during periods of activity, such as loading and when vehicles are stationary, the values for total metabolic heat output and water vapour could be expected to double (Mitchell and Kettlewell, 2008). Knowledge on the metabolic heat and water vapour output at different stages of transport for a specific weight classification of pigs can be used to estimate the minimum ventilation requirements for temperature ranges, using the equation: [VFR = TMHP/Cp $\times$ ΔT], where: VFR = flow rate (m^3/s); TMHP = total metabolic heat production (J/s; with J/s equivalent to W); Cp = specific heat capacity of air (1,226 J/m^3 per °C); ΔT = acceptable rise in air temperature (°C) (Mitchell and Kettlewell, 2008). This calculation can be used as an estimation of the ventilation requirements from which to develop and test vehicle ventilation ability under varying conditions. However, this equation does not account for heat loss through the vehicle and does not address partitioning of heat loss between sensible and latent heat (Mitchell and Kettlewell, 2008). The stocking density of a vehicle should consider the ventilation capacity of the vehicle, to ensure that sufficient ventilation can be maintained when it is in use for a specific type and age of pigs (Randall, 1993).

When trucks are stationary, for example for loading and unloading, the risk of heat stress increases. The internal temperature has been measured to increase up to 1°C/min (Weschenfelder et al., 2012; Xiong et al., 2015) in stationary, naturally ventilated vehicles carrying finisher pigs, the extent of the increase being influenced by the environmental temperatures, and type of pig, type of vehicle and space allowance. This evidence suggests that naturally ventilated vehicles therefore must have sufficiently large (or alternatively properly designed) ventilation spaces, to reduce heat build-up when stationary, or that the addition of mechanical ventilation should also be provided and be turned on (see also EFSA, 2004).

However, there exists very little information on how effectively different transport ventilation designs are able to keep pigs within the required temperature ranges when using mechanical vs passive ventilation. Further research is needed in this area. Vehicle designs and ventilation capacities must enable the animals to be transported safely within the required temperature ranges, depending on the local climatic conditions through which the vehicle will travel. Considering the transport of heavier pigs, with higher metabolic outputs, and the potential for increasing microclimatic extremes with climate changes, this is an area that should receive further research.

D) Thermal heat indices

Several indices have been developed to predict stressful environmental conditions that take into consideration multiple weather-related factors and allow execution of abatement strategies. The majority of these have been based on ambient temperature and relative humidity. One, the temperature–humidity index (THI) (as originally described by Thom, 1959), has been taken up by the livestock industry as a weather safety index to monitor and reduce heat-stress-related production losses. The fact that this use of THI thresholds is mainly focused on avoiding production losses, such as in-transit mortality, means that it is not necessarily aligned with animal welfare, as defined by affective states. Recent studies have called for further development of indices used to assess heat stress in livestock due to limitations in for example THI, such as (1) lack of integration of all environmental parameters; and (2) either not reflecting current high producing animals or not specifying production level. Factors like these may limit the usefulness of the indices to accurately predict or assess the thermal status of pigs and other livestock (Herbut et al., 2018; Mayorga et al., 2020). THI has, however, been used to quantify heat stress in studies of pig housing and transport (e.g. Lucas et al., 2000; Weschenfelder et al., 2012, 2013; Fox et al., 2014; Xiong et al., 2015; Pereira et al., 2018; Moak et al., 2022a,b), and studies quantifying THI have also been included in the data underlying the conclusions of this Opinion.

To avoid the limitations presented by the different available THI's or other comparable indexes, psychrometric principles (related to the humidity and temperature of air) have been used to develop other thermal comfort indexes, such as the specific enthalpy of air (de Castro Júnior and Silva, 2021). Enthalpy is the heat energy of the air surrounding an animal, and dictates the degree of heat loss to the microclimate. Physically, the specific enthalpy of air (h) is defined as the total amount of energy existent in a unit of dry air mass (kJ/Kg of dry air) and can be calculated using simple tools, such as thermometer and hygrometer, and mathematical models, as recently reviewed by De Castro and Da Silva (2021). In the future, time derivatives of temperature or enthalpy could be used as non-invasive welfare indicators during animal transport and appear to be more sensitive than values of temperature or RH. Even though enthalpy has been reported in some studies in relation to the quantification of heat stress in pigs during transport (e.g. Dalla Costa et al., 2019; Machado et al., 2021; Miranda-de la Lama et al., 2021), at the present stage, it is considered that too few data are available to be able to give recommendations based on enthalpy. Thus, this Scientific Opinion focuses on the temperature immediately surrounding the pigs and measures of humidity. The combined ambient temperature and RH can be reported by different indices, such as wet-bulb temperature (Twb), apparent equivalent temperature (AET), previously used by Mitchell (2006) to assess heat stress during transport of broilers, or Enthalpy Comfort Index (ECI) employed in tropical regions as a qualitative indicator of thermal environment of livestock (Rodrigues et al., 2011). However, none of these indices have been validated for pigs during transport.

Irrespective of the index chosen to monitor temperature and humidity, vehicles should be equipped with sensors recording temperature and humidity as close as possible to the position of the animals therein, and at several locations to include hot as well as colder spots (Figure 7). The livestock driver should then monitor the microclimate of the load and adjust the ventilation if the conditions exceed the TCZ levels. Technical issues (e.g. accuracy, maintenance, placement, reliability and calibration) relating to this improved approach will need to be addressed (Samad et al., 2020).

E) Identification of microclimatic conditions to protect pigs from heat stress during transport

In general, as discussed by Bracke et al. (2020), studies of heat stress in pigs have focused on housing conditions, and to a much lesser extent on transport conditions. This means, that knowledge considered in this Scientific Opinion is a combination of information from studies done on-farm and during transport. The vast majority of studies of heat stress in pigs have focused on finishers. In recent years, also sows have received scientific attention in terms of heat stress, but almost only in relation to on-farm productivity and welfare (e.g. Bjerg et al., 2020), whereas only a few studies have focused on heat stress during sow transport (e.g. Thodberg et al., 2019, 2022). Similarly, for weaners of ~ 30 kg, the category of pigs typically transported long distances in Europe, only very limited information exists about heat stress during transport (Averós et al., 2010).

The predominant physiological responses measured as indicators of heat stress in pigs under experimental conditions – often involving respiration chambers (Noblet et al., 1989; Tauson et al., 1998) or temperature chambers (Brandt et al., 2022) – are respiration rate (RR) and rectal temperature (RT) (as reviewed by Mayorga et al., 2019). Some focus has been given to indicators of productivity, such as voluntary feed intake or average daily gain (Huynh et al., 2005), and more recently, also behavioural indicators have been included. Examples of these are thermal preference studies (Robbins et al., 2021). Without any detailed quantification, Tauson et al. (1998) described how the boars in their study of heat stress showed behavioural responses, such as restlessness and biting the fixtures of the respiratory chambers. In a study involving gilts exposed to temperatures of 15–30°C while kept in individual crates, Canaday et al. (2013) observed increased occurrence of postural changes, increased lying, and increased lateral lying at the highest temperature.

In this Opinion, ABMs relevant for the study and the documentation of heat stress in pigs during transport have been listed in Section 3.2.2. An early response of pigs to increasing thermal load is to increase the RR, and thus the respiratory evaporative heat loss. 'First, a rapid shallow breathing called thermal polypnea leads to an increase in the amount of air passage through the upper region of the respiratory tract. When temperature continues to rise, the thermal polypnea shifts to a slower, deeper, panting phase (thermal hyperpnea) characterized by an increase of alveolar ventilation rate' (Renaudeau et al., 2012). As defined by Collier and Gebremedhin (2015), 'panting is, a controlled increase in respiratory frequency in concert with a decrease in tidal volume, which increases ventilation in the upper respiratory tract while preserving alveolar ventilation. The increase in upper respiratory tract ventilation increases evaporative heat loss'. Operationally, panting is often recognised by open mouth breathing, and this behaviour has been reported in pigs before, during and after transport.

The identification of the upper threshold of the TCZ is less certain than identification of the UCT, as it is challenging to identify a point where a response starts, as compared to the identification of a significant increase (or decrease) in a response. The current work has been based on the available scientific literature, and especially knowledge presented in two reviews of scientific literature focusing on heat stress in pigs (Bjerg et al., 2020; de Castro Júnior and Silva, 2021). The conclusions are given for the three main pig categories relevant for transport: weaners < 50 kg, finishers, and sows and boars. Table 15 summarises information from the literature.

Table 15: Summary of literature findings and suggestions for upper threshold of TCZ and for UCT. For each of the references, the reported dry temperature is listed, as well as the primary ABM used in the studies

Pig category	Upper threshold of TNZ	Upper critical temperature	ABM
	Temperature (°C)	Temperature (°C)	
Weaners			
Collin et al. (2002)	25 15–22 kg		RT
Renaudeau (2005)		LW[b]: 28–30 Creole[b]: 30–32 28–55 kg	RT
Hörtenhuber et al. (2020)[a]		8–30 kg: 30 30–60 kg: 25	
Market weight			
Gourdine et al. (2021)[a]	22	25	
Huynh et al. (2005)	22	Gilts, 60 kg: 26	RR, RT
Hörtenhuber et al. (2020)[a]		60 kg: 24	
Sows and boars			
Robbins et al. (2021)[c]	Sows: 16		Preference for staying
Gourdine et al. (2021)[a]	Sows: < 18	Sows: 22	
Ribeiro et al. (2018)[a]	15–25 Lactating sows		
Bortolozzo et al. (2011)	16–22 Sows		
Quiniou and Noblet (1999)		18 Lactating sows	RT
Tauson et al. (1998)		Boars: 30–32 100 kg	RT
Bjerg et al. (2020)[a]	< 20 Sows	22 Sows	RR
Hörtenhuber et al. (2020)[a]		After weaning: 24 Lactating 22 Boars: 19	

TNZ: thermoneutral zone; UCT: upper critical temperature.
(a): Reference is a review.
(b): Study involving sows that were either non-pregnant or early-mid pregnant.
(c): When available, the pig breed is specified.

For all three pig categories, the scientific literature shows some variation in the reporting of the upper threshold of the TNZ and of UCT. As discussed by Bjerg et al. (2020), these differences can be explained by the difference in the use of ABMs, differences between breeds, housing or feeding, and also often that studies are comparing two or more environmental conditions, and thus can in principle not predict clear thresholds, but only report differences between, for example, ambient temperatures of 20°C and 30°C. In addition, the age span of the reported studies is wide, which means that results will also be affected by the consequences of the selection for increased productivity. In recent years, the vulnerability of sows towards heat stress has received increasing scientific focus. In their review of studies focusing on this topic, Bjerg et al. (2020) compared results from available studies. Figure 8 shows their findings of RR as a function of air temperature reported in different studies. Based on these data, the authors concluded that the upper threshold of the TNZ for lactating sows may be lower than 20°C, and that UCT is ~ 22°C.

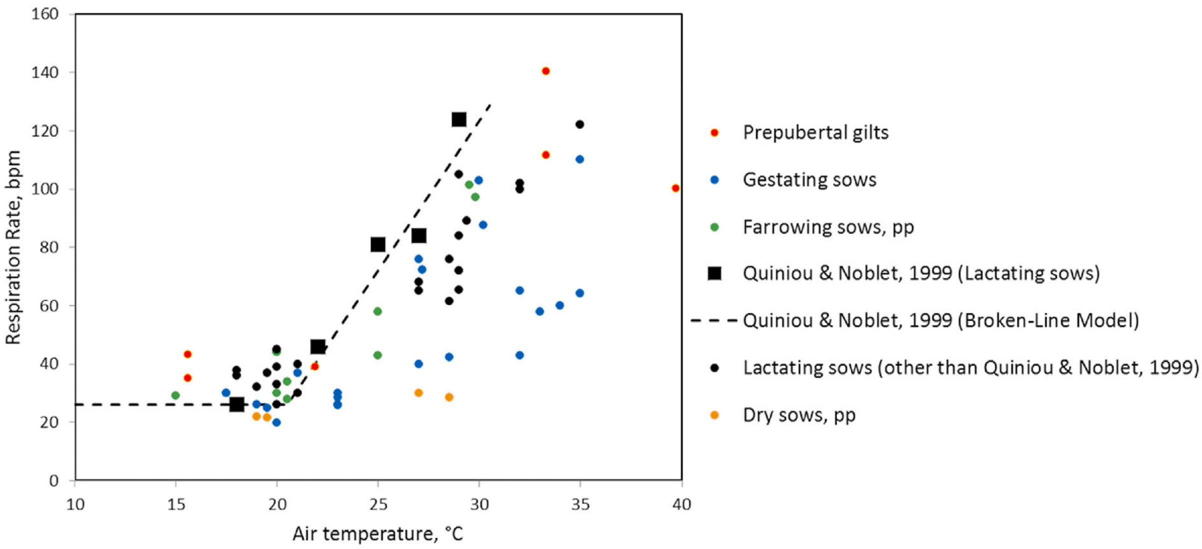


Figure 8: Respiratory rate of sows as a function of air temperature, including data from several studies (Bjerg et al., 2020)

The thresholds suggested by Bjerg et al. (2020) are overlapping with findings from other studies. In their study, based on the establishment of a mechanistic thermophysiological model for sows (Huang et al., 2021a,b), Huang et al. (2022) concluded that when RH > 60%, the effect of a 10% increase in RH on the thermophysiological responses of gestating sows is equivalent to the effects of 1°C increase in ambient air temperature.

For finishing pigs, the available studies suggest that the upper threshold of the TNZ is 18–22°C, and that UCT is in the interval from 24°C to 27°C. Weaners are less sensitive to heat stress than the two other categories because of their lower bodyweight. For weaners, the available studies suggest that the upper threshold of the TNZ is ~ 25°C, whereas UCT corresponds to ~ 30°C. These values might, however, depend on whether the weaners are closer to 10 kg body weight, or above 30 kg, and far from the actual weaning transition period, when feed intake may be low.

Tolerance and adaptation

At present, pig breeding programmes are not including traits associated with thermoregulation, although these are now the subject of investigation by some breeders. Unless such traits are integrated in selection indices, pigs of the future will likely not be more resistant to heat stress than the pigs of today (Gourdine et al., 2021), but may be even more vulnerable (Renaudeau and Dourmad, 2021).

Studies do, however, suggest that there are breed differences in the thermal tolerance of pigs (Tauson et al., 1998; Sejian et al., 2018), and also that acclimatisation to a hotter environment to some extent might be possible, but will take days to weeks (Renaudeau et al., 2010; Collier et al., 2019). It has not been possible to find data to clarify whether pigs of certain breeds, or from certain regions of the EU, are better adapted to hot conditions than others. This constitutes a gap in knowledge.

F) Summary of microclimatic conditions

Pigs are special among mammals and have difficulty in dissipating heat as their sweat glands are almost non-functional (Ingram, 1965). Thus, pigs are more vulnerable to heat stress than most other farm animals. Across the different pig categories, there is growing evidence that genetic selection for productivity and more efficient accretion of lean tissue, has increased their metabolic rate and reduced pigs' ability to cope with heat stress (Mayorga et al., 2019; Mutua et al., 2020; Gourdine et al., 2021).

Larger pigs, especially lactating sows, are more vulnerable to heat stress than smaller pigs. The available information for boars is very limited. Compared to the other categories of pigs, typically subjected to transport, weaners are likely to be the least vulnerable to heat stress.

It has not been possible to find data to clarify whether pigs of certain breeds, or from certain regions of the EU are better adapted to sustain heat stress than others. This constitutes a gap in knowledge.

If a negative impact on animal welfare from the microclimatic conditions during journeys is to be fully prevented, pigs should be transported in their TCZ. This means that, during transport of pigs, the WC, heat stress, may start when pigs are no longer in their TCZ, and the risk and severity of heat stress is likely high when the thermal conditions reach the UCT.

Not only the temperature, but also other environmental conditions influence heat load placed on pigs during transport, such as humidity, thermal radiation, temperature of surrounding surfaces, wind speed, and the opportunity for pigs to moisten their skin. These will all influence the microclimatic conditions experienced by pigs and should, in theory, all be taken into account when microclimatic conditions of pigs during transport are evaluated.

The available information on thermoregulation of the three relevant categories of pigs, is not fully unambiguous, but has allowed for estimates of upper thresholds of the TCZ, and for the UCT to be derived.

For sows, the upper threshold of the TCZ may be lower than 20°C, and that the UCT is ~ 22°C. For finishing pigs, the available studies suggest that the upper threshold of the TNZ is 18–22°C, and that the UCT is in the interval from 24°C to 27°C. Weaners are less sensitive to heat stress than the two other categories because of their lower bodyweight. For weaners, the available studies suggest that the upper threshold of the TCZ is ~ 25°C, whereas the UCT corresponds to ~ 30°C. For variations of dry temperature and relative humidity, the higher the levels of relative humidity, the lower the upper thresholds of TCZ and UCT will be, when measured as a dry temperature only.

Although sensors recording dry temperature have commonly been used in transport of pigs so far, it would be a significant refinement to use improved sensors taking account of humidity effects in addition to temperature.

3.5.3.2. Threshold of space requirements during journeys

A) Introduction and methodology

The stocking or loading density refers to the live weight of pigs within a specified area of floor space (or occasionally the number of pigs of a specified live weight range per unit area). The space allowance can be quantified as the floor area per animal. In this Scientific Opinion, space allowances are given as m^2 per animal, as well as the estimated k-value for the allometric equation for space allowance (Petherick and Philips, 2009).

The spatial dimensions of compartments holding pigs during transport are important for their welfare – in the horizontal as well as the vertical plane - and a lack of space may lead to several WCs, such as group stress, injuries, restriction of movement, resting problems and heat stress.

Due to the limited research available, the multiple factors that can influence how pigs respond to space during transport, the variability in types of pigs and in journey conditions, it is considered preferable to provide minimum rather than target or recommended space allowances for different types of pigs. The evidence of WCs when inadequate space is available is stronger than that available for determining optimal conditions.

Multiple factors affect the use of space by pigs during transport, including the age and category of pig (weaner, finisher, sows/boars), microclimatic conditions and journey duration. Body weight and dimensions change with the pig category and age (Condotta et al., 2018), and are related to the space required (Arndt et al., 2019, 2020). It is, thus, a complex issue to provide a minimum recommended space allowance during transport that will be applicable within all situations. If the minimum recommended space allowance is set too low for a particular situation, it will likely increase the risk of adverse WCs.

In the assessment of minimum space requirements for pigs during transport, the following approach will be used:

During transport, pigs require a minimum space allowance that will accomodate (a) their physical size in a standing (or sternally lying) posture, and thereby allow them to (b) adjust their posture in response to acceleration and other events, (c) rest in a normal semi-recumbent lying posture, (d) thermoregulate, and (e) eat and drink, if feed and water are provided in the means of transport. Recommendations for a minimum space allowance will be set by the first limiting factor that reduces the ability of the pigs to undertake one of the above biologic requirements, i.e. whichever of the above requirements needs the most space.

The section also discusses compartment height, as another dimension of space, and WCs, hazards and AMBs listed above for the transit stage (Sections 3.2.2 and 3.5.2) are used to draw conclusions.

B) Horizontal space

i) Space to accommodate physical size

The space occupied by pigs in a standing or sternally lying posture depends on the size of the animals, and allometric equations are available that relate live weight to floor space. Allometric equations ([$A = kW^{2/3}$], where k is a constant and W represents live weight in kilograms) are used to estimate the space that a stationary animal occupies as a consequence of its mass (Petherick and Philips, 2009). The power factor is derived from theoretical relationships between length, volume, weight and surface area (Warriss et al., 1998). Using an exponent of 2/3 makes the assumption that all pigs have a similar shape. Therefore, allometric equations provide estimates of space requirements rather than definitive calculations of areas. Variations in the k-values used in allometric equations produce a range of recommended space allowances for each live weight range (Warriss et al., 1998; Visser, 2014).

Using allometric equations it has been proposed that the space requirement for animals in a group to stand or lie sternally (legs tucked close to and under the body) can be estimated from k = 0.019 (Petherick, 1983, cited by Ekkel et al., 2003). However, differences in how pig categories socially interact will affect the use of space, as shall be discussed below.

Weaners: It is common practice in areas of Europe for newly weaned piglets to be transported short distances to nursery barns (multisite, integrated production) and for weaners of around 30 kg to be transported to rearing barns for further fattening (Dahl-Pedersen and Herskin, 2021). The transport of newly weaned piglets can pose unique challenges due to their size, having lower body reserves and being less tolerant of cold stress.

There is limited published work on the effect of space allowance on the transport of weaned piglets. Therefore, the limited studies that are available for weaned piglets have been reviewed, and other studies on very young piglets, weaned earlier than the current practice in the EU were also included. The physical space requirements to stand and lie sternally based on a k-value of 0.019 ranges from 0.09 to 0.18 m^2/pig for piglets ranging from 10 to 40 kg, respectively (Table 16). For 18-day old piglets (~ 5 kg), transported in summer in the Southern United States for journeys of 2–3 h, Sutherland et al. (2010) suggested that 0.06 m^2/piglet (corresponding to a k-value of 0.021) provided space for sternal lying. In the same study, transporting pigs at a lower space (0.05 m^2/pig) increased the neutrophil:lymphocyte ratio, suggestive of physiologic stress/and or inflammation, while reduced lying and increased standing was found when they were transported at 0.07 m^2/pig, which was interpreted as possibly indicating increased instability (Sutherland et al., 2010).

Newly weaned piglets show a natural propensity to overlie even when a larger space allowance (k-value of 0.039) is provided (Kaur, 2018). No benefits have been found when providing greater space allowances for piglets weaned very early and transported shortly after weaning (6–10 kg) on short trips of up to 1 h at (0.064, 0.084 or 0.145 m^2/pig), with piglets huddling, and all available floor space not utilised (Riches and Guise, 1997). Thus, from the point of view of providing the pigs with space enough to lie sternally, their tendency to overlie at this age may mean that they in practice will be able to lie down, even with less space than corresponding to a k-value of 0.019, at least as long as they are kept in their TNZ.

For weaners in nursery housing, the average number of pigs performing overlying behaviour has been observed to reduce in pigs nearing 25 kg in weight (42 and 63 days of age) compared to pigs in the first week after weaning (25–28 days of age), when kept under thermoneutral conditions (Kaur, 2018). Therefore, for weaner pigs (10–40 kg) a space allowance as calculated for a k-value of 0.019 will likely be required for all animals to lie down sternally (Table 16). It should be acknowledged though, that there is insufficient evidence for how weaners will perform during transport at this space allowance.

Table 16: Minimum space requirements for weaners (10-40 kg) to stand or lie sternally (k-value: 0.019)

Pig weight (kg)	m^2/pig	kg/m^2
10	0.09	112.5
20	0.14	141.4

Pig weight (kg)	m^2/pig	kg/m^2
30	0.19	161.7
40	0.22	177.8

Finishers: Within the EU, pigs are transported by road to abattoirs for slaughter. While the average EU slaughter weight for finisher pigs is 124 kg (ADHB, 2021), the 'heavy pig,' reared in some Mediterranean MS, for the production of certain meat products, is slaughtered at ~ 150–170 kg (Zappaterra et al., 2022).

Image analysis quantifying the area occupied by pigs of different weights and different postures provide data to compare to that estimated by allometric equations. Contrast-based planimetric analysis of images determined that the space occupied by finishers (mean 109 kg) is influenced by the weight and posture of the animals. Standing space ranged from a low of 0.29 m^2 for a pig standing straight with the head down, to a high of 0.33 m^2 for a pig standing with the head up and a curve in the body (Arndt et al., 2019), providing a space lower than that calculated by a k-value of 0.019. A pig lying on its sternum occupied between 0.43 and 0.44 m^2 (Arndt et al., 2019), a value that is aligning to the space required for a 110-kg pig as calculated from a k-value of 0.019 (Table 17).

Heavy finisher pigs (150–170 kg): Given that static space requirements relate to the weight of the pig (Arndt et al., 2019) and that this relationship is not linear, it is important that specific space requirements for heavy finishers are given consideration. Heavy finishers likely have different space requirements due to their increased size, metabolic output, large muscle mass and low cardiac output (van Essen et al., 2018), altogether making these pigs more susceptible to stress and mortality during transport. Heavier pigs have an increased heat output (+2% for every additional 5 kg of liveweight; Brown-Brandl et al., 2004), and a reduced ability to dissipate heat (Renaudeau et al., 2011) making them more susceptible to heat stress. However, even though pre-slaughter data on death loss of Italian heavy pigs (~ 160 kg) has identified that 56% of losses occur during transport, space allowance during transport was not identified as a risk factor (Nannoni et al., 2017). However, given the limited research in this area, studies to investigate the effect of space allowance should be performed. Based on a lack of available evidence on how heavy finishers respond to space allowance in transport, the minimum space required for these to stand up and lie down sternally, without additional room to manoeuvre between positions, can be calculated based on allometric equations with a k-value of 0.019 (Table 17).

Table 17: Minimum space requirements for finishing pigs to stand or lie sternally (k-value 0.019)

Pig weight (kg)	m^2/pig	kg/m^2
100	0.42	240.6
110	0.44	248.3
120	0.47	255.5
130	0.50	262.3
140	0.52	268.8
150	0.55	275.0
160	0.57	280.9
170	0.59	286.6

Sows, gilts and boars: Within the EU, gilts (130–180 kg) are transported to farms as replacement breeding animals, and sows at the end of their productive life are transported to slaughter. According to Dahl-Pedersen and Herskin et al. (2021), the number of pigs transported between EU MS for breeding has been quite variable during the last years, ranging from less than 1 million to more than 3 million per year due to a volatile market. For sows, Blair and Lowe (2019) stated that across pig producing countries, a culling rate of up to 50% per year is not unusual, which means that a considerable number of sows are sent to slaughter each year. In the EU, the majority of sows are probably slaughtered in the country of origin, but some are transported to other MS for slaughter.

While there is variation in genetics and between countries, there is evidence that at least in some genetic lines, the size of sows has steadily increased in the last three decades, with sows becoming heavier and longer (Moustsen et al., 2011). However, comparing sow dimensions for length, width and height between that calculated by the allometric equations proposed by Petherick and Philips (2009) to the measurements taken by Moustsen et al. (2011), in Danish sows ranging from parity 1 to 7, indicates that the allometric equations continue to provide close estimations of the body dimensions of these modern genetics.

Planimetric analysis of the static space floor area occupied by sows in different postures (average sow weight 235 kg, min: 187; max: 310 kg) has identified that when standing, the occupied floor area ranges from 0.42 m^2 to 0.47 m^2 (min: 0.34; max: 0.59 m^2), and sternal lying requires an average floor space of 0.63 m^2 (min: 0.52; max: 0.71 m^2), (Arndt et al., 2020). This is lower than the minimum space allowance estimated for sows to stand and lie sternally as calculated with a k-value of 0.019. Despite these recent findings, in the face of a lack of evidence on how space allowance during transport influences sow behaviour and welfare, a minimum space requirement for sows to stand and lie sternally should be based upon the minimum space calculated from allometric equations with a k-value of 0.019 (Table 18).

Table 18: Minimum space requirements for sows to stand and lie sternally (k-value 0.019)

Pig weight (kg)	m^2/pig	kg/m^2
180	0.62	292.1
200	0.66	302.4
220	0.70	312.1
240	0.75	321.2
260	0.79	329.8
280	0.83	337.9
300	0.87	345.7
320	0.91	353.1

ii) Space required to adjust posture in response to acceleration and other events

During road transport, the space allowance provided to pigs needs to accommodate not only their static space, but additionally space to change and adopt postures to balance and stabilise themselves during vehicle movement, for example during the navigation of corners, acceleration and braking.

Theoretically, both low and high space allowance could increase injury to animals during driving events. Injury in the form of bruises, superficial skin lesions and open wounds will increase if the space allowance is low, resulting in a greater risk for pigs to become trampled, trapped or crushed by others in the load. Lameness can also increase as a result of injuries sustained, and the inability of pigs to adequately stabilise themselves, and achieve a comfortable position throughout the transit stage. Earlier (AHAW, 2002), it has been discussed whether animals, in situations of poor driving or emergency responses, could benefit from a stocking density that provided mutual support, i.e. whether a high space allowance, could also reduce the ability for pigs to adequately stabilise themselves during the journeys. Evidence from other species (Jones et al. (2010) in sheep and Tarrant et al. (1992) in cattle) indicates, however, that if vehicles are driven well on good quality roads, the animals benefit from plenty of space, suggesting that slips and falls in relation to space allowance on the vehicle, are mainly associated with low space allowance, and that animals need increased space compared to stationary conditions to adopt postural changes to brace themselves while standing, and to adjust their footing in order to maintain stability in response to changes in acceleration (including braking, stopping and changes of direction). This has, however, not been investigated in pigs and constitutes a gap in knowledge.

Weaner pigs: There is no literature available observing how piglets adjust posture in response to driving.

Finisher pigs: There is little available evidence of how space allowance influences the ability of pigs to stabilise themselves during driving events of transport. The extent of injury pigs receive during transport is commonly reported, which may indicate increased risk of injury if space allowance is too great or too small (Barton Gade and Christensen, 1998; Urrea et al., 2021). However, it should also be noted that many trials do not describe whether the pre- and post-transport handling has been controlled for, which could contribute to incidence of injury and bruising.

On long durations of transport ($\geq$ 25 h), pigs have been observed to be more active at lower space allowances, repeatedly changing posture because all animals cannot lie down at once (Lambooij et al., 1985; Lambooij and Engel, 1991). While the available data may suggest there is a balance to be struck between too low and too great a space allowance. Observations on lying behaviour (Section iii) suggest that when provided with extra space, pigs will use it (Lambooij and Engel, 1991) and will remain recumbent while the vehicle is moving (Gerritzen et al., 2013), particularly on longer journeys. The evidence of greater injury does also suggest that more careful driving is required if pigs are to be transported at larger space allowances, for it could increase the risk of injury. Thus, even though too much space might be counterproductive on shorter journeys, evidence suggests for longer journeys, if vehicles are driven well on good quality roads, pigs benefit from space.

Sows, gilts and boars: There is no research available to provide information on how space allowance during transport influences the ability of sows, gilts and boars to stabilise themselves during transport. This is a knowledge gap that needs to be addressed. The clinical condition of cull sows transported on journeys of up to 8 h has been observed to deteriorate during transport to slaughter at a space allowance of 0.80 m^2/250 kg sow (Thodberg et al., 2019), further warranting the need for further study of the behaviour of sows while on the vehicle to determine what occurs on these journeys.

iii) Space required to rest in a normal semi-recumbent lying posture

Whether pigs require the space to lie down and rest on a journey is dependent on age of pigs, category of pig, journey duration, condition of the pigs and within vehicle microclimatic conditions. Loading and transport are stressful for pigs, and ensuring pigs have sufficient space to lie down and rest on the journey may help them to recover and prevent the WC resting problems, and the development of fatigue. In terms of space requirements, it has been proposed that allometric equations should use a k-value of 0.027 to calculate the minimum space required for a group of animals to lie down and rest simultaneously (Petherick and Philips, 2009). The space allowance provided at a k-value of 0.027 does not accommodate additional space required for manoeuvring between a lying and standing posture. However, given that pigs do show evidence of space sharing (not all animals lying down at once, or for young pigs, more overlying behaviour), the space provided at this k-value could be considered a first step to providing enough space for all animals to lie down over the course of a journey.

Weaners: Observations from limited studies, and personal observations of researchers suggest that when transported, newly weaned pigs (21–28 days of age) are inclined to lie down rapidly from the start of the journey, sometimes lying down shortly after loading (Y. Seddon, University of Saskatchewan, personal observation on newly weaned piglets).

In older weaner pigs, the speed at which they lie down may be more variable. Magnani et al. (2014) reported a reduction in activity of 13-14 kg piglets following 4 h of transport. The minimum space requirement for a group of weaner pigs to simultaneously lie down is given in Table 19.

Table 19: Minimum space requirements for weaner pigs (10-40kg) to simultaneously lie semi-recumbent (k-value 0.027)

Pig weight (kg)	m^2/pig	kg/m^2
10	0.13	79.2
20	0.20	99.5
30	0.26	113.8
40	0.32	125.1

A space allowance of 0.15, 0.18 or 0.23 m^2/pig (corresponding to a k-value of 0.016, 0.019 and 0.024, respectively) was not found to influence the heart rate, salivary cortisol or postures of 30-kg weaner pigs during commercial transport (mean duration: 3.5 h, internal vehicle temperature: 13–15°C). Observations of postures found that almost half of the pigs sat or lay during the journey, with pigs choosing to huddle together, leaving free floor space (Riches et al., 1997; Riches and Guise, 1997). Environmental conditions being below the TNZ of 30-kg piglets may contribute to the overlying; overlying has been observed to reduce in 25-kg pigs in nursery housing under thermoneutral conditions (Kaur, 2018).

In observations from 4 loads of 5-week-old piglets (estimated 13–14 kg) transported one week after weaning, for 14 h, at a space allowance of 0.15 m^2/pig, equivalent to k-value = 0.027, on average 65% of the piglets lay down within the first 4 h, changing to 77% of piglets after 10 h

(Magnani et al., 2014). When the majority of the piglets were lying, the second most frequent posture was standing, with low levels of exploratory and social behaviours observed to occur throughout the journey (Magnani et al., 2014). Aggressive behaviour was observed during transport, but at a higher frequency in pens mixed prior to loading (on-farm), than pigs mixed at loading (Magnani et al., 2014).

Observations suggest that in very early weaned piglets transported immediately after weaning (17 days of age), normal social behaviours (fighting commencing between unfamiliar pigs) will take place, which has been observed in North American journeys of long duration (up to 24 h) and space allowance of 0.06 m^2/pig (Lewis and Berry, 2006). However, during transport at night, weaners of 20–25 kg transported at a space allowance of 0.18 m^2/20 kg (between k-value 0.024 and 0.03 depending on pig weight) pigs have been observed to all lie down (C. Kobek-Kjeldager, Aarhus University, personal observation) as seen in Figure 9, and therefore the use of space sharing may depend on factors, such as age, space allowance and the time of day.

This limited evidence suggests that a space allowance calculated from a k-value of 0.027 could be

Figure 9: Photo taken with fish-eye lens from video recordings of the behaviour of 20- to 25-kg weaners during transport. Taken during driving, after 03:47 h of driving. The pigs were transported for 8 h at commercial Danish density (0.155 m^2/pig weighing 22 kg, corresponding to a k-value of 0.019). The deck height was 70 cm and the mean outdoor temperature of the day was 21°C. Photo by C. Kobek-Kjeldager, Aarhus University)

sufficient to provide lying space and (on the basis that typically not all animals will lie down at the same time, or that some huddling will take place) may also accommodate behavioural activities in young pigs transported. It could be expected this may include moving around the compartment and being able to change posture.

Finisher pigs: The minimum space allowance for finishers, both standard and heavy, to simultaneously lie semi-recumbent is provided in Table 20. Lambooij and Engel (1991) reported that transporting finisher pigs (110 kg) at 232 kg/m^2 (k-value: 0.021) provided just enough room for all animals to lie down sternally. However, pigs lay down sooner in the journey when provided with 0.59 m^2/pig (186 kg/m^2) - equivalent to a k-value of 0.025.

Table 20: Minimum space allowance for finisher pigs to simultaneously lie semi-recumbent (k-value 0.027)

Pig weight (kg)	m^2/pig	kg/m^2
100	0.59	169.3
110	0.63	174.7
120	0.67	179.8
130	0.70	184.6
140	0.74	189.2
150	0.78	193.5

Pig weight (kg)	m^2/pig	kg/m^2
160	0.81	197.7
170	0.84	201.7

Urrea et al. (2021) compared the behaviour and physiology of finishers (~ 118 kg) transported for 8 h at either 0.5 m^2/100 kg (k-value: 0.021), 0.43 m^2/100 kg (k-value: 0.018) or 0.37 m^2/100 kg (k-value: 0.015). A greater proportion of pigs lay down during the journeys when transported at 0.5 m^2/100 kg and 0.43 m^2/100 kg than 0.37 m^2/100 kg suggesting on longer journeys with available space, pigs will lie down. Additionally, a greater proportion of pigs adopted a sitting posture when transported at 0.37 m^2 than 0.5 m^2, with pigs transported at 0.43 m^2 being no different. Upon arrival in lairage, a greater proportion of pigs transported at 0.37 m^2 lay, while pigs transported at 0.5 m^2 and 0.43 m^2 stood more (Urrea et al., 2021). Together these data indicate that having sufficient space to lie down during transport can help to reduce fatigue on longer journeys, with failure for sufficient space resulting in more compensatory postures and a greater fatigue in pigs upon arrival.

There are no published studies of finisher pigs transported at space allowances within the range proposed in Table 20. There is one study exploring the effect of transporting pigs 550 km at a space allowance of 0.59 m^2/pig for 110-kg pigs, equivalent to a k-value of 0.0255 (Gerritzen et al., 2013). Based on findings of increased resting behaviour and lower body temperature and heart rate, the authors concluded that pigs are more capable of adapting to long transport conditions when loaded at a density below what was required in the EU at the time of the study (0.47 m^2/pig, equivalent to k-value = 0.0205).

Studies of the behaviour of finishers during transport have shown that during shorter (2 h) journeys, pigs spend a numerically greater proportion of observations standing (mean: 46%) than lying (8%), (Torrey et al., 2013a). On longer journeys (8 h), pigs have been observed lying for a numerically greater proportion of observations (lying: 52% vs. standing: 16%) (Torrey et al., 2013b).

Transporting finishers (110 kg) at 0.59 m^2/pig (k-value of 0.026) resulted in more fighting activity between mixed pigs, but also more pigs lying down and remaining recumbent throughout the journey compared to pigs transported at 0.42 m^2/pig (k-value of 0.018): three hours into the journey 60% of pigs in the low-density treatment were recumbent compared to only 20% in the commercial density treatment (Gerritzen et al., 2013), providing more evidence that given the space, pigs will use it to rest. Given that transport, especially long journeys, are fatiguing for the pigs, it is considered the pigs need to have the space to lie down and rest.

Sows, gilts and boars: There is a lack of published data from which to provide evidence for the requirements of sows, gilts and boars to simultaneously lie semi-recumbent. In this absence, the minimum space requirements as calculated by allometric equation are provided (Table 21).

Table 21: Minimum space requirement for gilts, sows and boars to simultaneously lie semi-recumbent (k-value 0.027)

Pig weight (kg)	m^2/pig	kg/m^2
180	0.88	205.5
200	0.94	212.8
220	1.00	219.6
240	1.06	226.0
260	1.12	232.0
280	1.18	237.8
300	1.23	243.3
320	1.29	248.5

iv) Space required to thermoregulate

The minimal space allowance that can protect the welfare of pigs during transport, will be influenced by the microclimatic conditions, i.e. temperature and humidity inside the vehicle, the effectiveness of the ventilation system (while the vehicle is in motion or stationary) and by the ability of the animals to thermoregulate effectively.

Increasing space allowance can reduce the risk of heat stress by reducing the number of animals, thereby reducing the total metabolic heat and moisture produced by the animals on board a vehicle.

Dewey et al. (2009) reported increased truck internal temperature by 7°C when load density increased from 1 to 3 pigs/m^2. Additionally, increasing the space allowance helps to increase the evaporative cooling mechanisms via increased exposure of body surface areas to ventilation. However, no research was identified to provide specific quantitative information on appropriate space allowances in relation to thermal conditions. Additional information on microclimatic conditions (temperature, humidity and ventilation) during road journeys of pigs can be found in Section 3.5.3.1. From this section, it is also evident that pigs lack functional sweat glands, and rely on their behaviour to thermoregulate. One such thermoregulatory behaviour is full lateral recumbency, by which the pigs maximise the contact between their body and the flooring, and thus may increase heat dissipation (Bracke et al., 2020).

The minimum space allowance required for pigs to lie in full lateral recumbency, legs outstretched and without space sharing between the legs, can be calculated using a k-value of 0.047 (Petherick, 1983a,b) (Tables 22–24). This provides a space allowance that is similar to the space allowance calculated to enable animals to lie down and move between a standing and lying position and vice-versa, which can be calculated from a k-value of 0.046 (Petherick and Philips, 2009). However, the synchronicity of behaviour should be considered. Gerritzen et al. (2013) reported that the activity of pigs transported differed by trip, although inadequate data were presented to show this. However, it does suggest that space sharing and changes in activity within groups of transported pigs will likely take place, and therefore provision of space for all animals to lie down in a fully recumbent position may not be necessary for animals transported in a group, if there will be changes in activity within the group and space sharing. However, for animals transported in individual pens, such as boars, additional space may be beneficial to enable posture adjustment and stretching of limbs. Therefore, when calculating the space requirement for animals that are transported individually, it may be better to be closer to a k-value of 0.047.

Digital image analysis of the area occupied by finisher pigs calculated the minimum static space requirements ranging from 0.65 m^2 for 100-kg pig to 0.84 m^2 for an animal of 160 kg to be fully recumbent, without space sharing (which means that the space between the legs is included per animal), equivalent to calculating space with a k-value of 0.028 (Pastorelli et al., 2006). Planimetric analysis calculated a finisher pig (average weight 109 kg) lying laterally required a space allowance of 0.49 m^2 (Arndt et al., 2019), much lower than that calculated from allometric equations.

At warmer temperatures, insufficient space for animals to spread out makes it challenging for pigs to dissipate heat effectively by conductive (insufficient surface area to lie in full lateral recumbency) and convection heat loss (insufficient movement of air around the pigs) (Hayley et al., 2010). An increased number of animals within a vehicle also increases the production of heat and water vapour. In warm weather, this can lead to a microclimate around the animals that increases heat stress, resulting in greater requirements for thermoregulatory behaviour to increase heat loss (Mitchell and Kettlewell, 2008), while also making evaporative heat loss from panting less effective. As discussed in Section 3.5.3.1, the uneven temperature distribution and heat zones in vehicles (e.g. Xiong et al., 2015), means that the space required to be able to thermoregulate in principle may differ in different compartments, even on the same vehicle.

Increasing the space allowance by up to 20% has been suggested to allow animals on longer journeys room for thermoregulation (Council Regulation (EC) No 1/2005[1]). It has, however, not been possible to find any scientific validation of this suggestion. Based on the data from Arndt et al. (2019), changing from sternal to lateral lying requires a 14% increase in space, which suggests that a recommendation of a 20% increase in space during warm weather conditions may be sufficient for pigs to be fully recumbent and thus perform thermoregulatory behaviour. The extent to which such an increase in space allowance will lead to reduced temperatures inside a vehicle, due to reduced heat production from fewer animals per m^2, is not known.

Table 22: Minimum space requirement for weaner pigs to lie in full lateral recumbency (k-value 0.047)

Pig weight (kg)	m^2/pig	kg/m^2
10	0.22	45.5
20	0.35	57.2
30	0.46	65.4
40	0.56	71.9

Table 23: Minimum space requirement for finisher pigs to lie in full lateral recumbency (k-value 0.047)

Pig weight (kg)	m^2/pig	kg/m^2
100	1.03	97.3
110	1.10	100.4
120	1.16	103.3
130	1.23	106.0
140	1.29	108.7
150	1.35	111.2
160	1.41	113.6
170	1.47	115.9

Table 24: Minimum space requirement for sows, gilts and boars to lie in full lateral recumbency (k-value 0.047)

Pig weight (kg)	m^2/pig	kg/m^2
180	1.52	118.1
200	1.64	122.2
220	1.74	126.2
240	1.85	129.8
260	1.95	133.3
280	2.05	136.6
300	2.15	139.8
320	2.24	142.8

During cold conditions, pigs require sufficient space to be able to move away from cold areas, such as air movement at ventilation inlets. Otherwise, they could experience the WC cold stress, involving discomfort and potentially distress, caused by, for example frostbite. In colder temperatures, pigs will increase body contact with conspecifics, adjust postures to reduce contact with cold surfaces, and huddle together to reduce heat loss (Hillman et al., 2004). Increased sitting behaviour has been observed in cold weather transport (Goumon et al., 2013), which has been associated with attempts for the pigs to reduce contact with cold surface areas.

v) Space requirements to eat and drink, if feed and water are provided on the vehicle

Due to the tendency of pigs to develop motion sickness (see Section 3.5) and studies suggesting that transport without fasting is associated with increased mortality in finisher pigs (Averós et al., 2008), it is possible that the provision of feed on-board vehicles – provided during driving or when stationary – will increase death loss in pigs. This warrants further study before spatial recommendations can be given. Hence, in this section focus will be on provision of water.

The minimum space allowance considerations when transporting pigs with access to water need to consider the space required for provision of nipple drinkers, along with the ability for pigs to manoeuvre to access these. There is limited research on the provision of water to pigs on vehicles, and no research is available exploring the design and positioning of the access to the water nipples on the vehicle. Sufficient provision of resources in terms of water and space for the number of animals per compartment must also be considered, and this will likely be influenced by the pig category. For pigs transported in groups, there are no available data to indicate how space allowance influences water use on-board. Of the limited studies available, water disappearance (amount of water left in tank after journey) has not been found to differ with space allowance (Gerritzen et al., 2013). No impact of loading density (0.42, 0.5, 0.6 m^2/pig) was reported by Chevillon et al. (2003) either.

B) Vertical space

Not only space allowance in the horizontal plane, but also in the vertical plane, may influence welfare of pigs during transport. Trucks used to transport pigs may have from 2 to 5 decks, allowing approximate deck heights from 120 cm to 60 cm, respectively, depending on the category of pigs transported. The majority of finishers are transported in multi-deck trucks with a deck height ranging from 90 to 112 cm (Weschenfelder et al., 2012; Visser, 2014; Moak et al., 2022a,b). The height of compartments within which pigs are transported influences their ability to adopt a comfortable unimpeded posture. In addition, it is necessary for adequate temperature regulation and removal of noxious gases that the height of the compartment is adequate for effective ventilation to occur (SCAHAW, 2002). Finally, the compartment height may also affect the manoeuvrability and ability of the pigs to locate resources such as preferred orientation and water sources, but at the same time, unrestricted compartment height may facilitate unwanted behaviours such as mounting or fighting. Overall, the available literature on the relationship between deck height and pig welfare is very limited which constitutes a gap in knowledge.

Equations to estimate pig height have been proposed by Petherick (1983a,b): [height (m) = $0.156W^{0.33}$], where W is the weight of the pigs (in kg) and by Foldager et al. (2021): [height (cm) = $15.5 + 2.06W - 0.0500W^2 + 0.000514W^3$] (Table 25). The development of the equation by Foldager et al. (2021) focused on pigs of less than 40 kg of body weight.

Table 25: Estimates of pig height (highest point of the back, constituting the highest point of the body when standing in a natural position) by two equations

Pig type	Pig weight (kg)	Average height (m)[(a)]	Height (cm)[(b)]
Weaner pigs	10	0.33	31.6
	20	0.42	40.8
	30	0.48	46.2
Market pigs	100	0.71	–
	120	0.76	–
	140	0.80	–
Heavy market pigs & gilts	160	0.83	–
	180	0.87	–
Sows & Boars	200	0.90	–
	220	0.92	–
	240	0.95	–
	260	0.98	–
	280	1.00	–
	300	1.02	–
	320	1.05	–

(a): Petherick (1983a,b).
(b): Foldager et al. (2021): Preliminary data, estimation using the polynomial equation only advised up to pigs of 40 kg.

The CATGP (2017) recommended best practice deck heights of the following: pigs 10–25 kg: 62 cm, pigs 100–120 kg: 88 cm, pigs > 120 kg: 100 cm. However, no scientific evidence to support this statement was found. In addition, there is evidence from North American trailer types that compartment temperature and RH may increase during stationary periods, when the deck height is less than 30 cm (for passively ventilated vehicles) or 15 cm (for mechanically ventilated vehicles) above the highest point of the pig's body (Weschenfelder et al., 2012; Moak et al., 2022a,b).

C) Summary of space requirements during journey

The spatial dimensions of compartments holding pigs during transport are of major importance for their welfare – in the horizontal as well as the vertical plane – and lack of space may lead to several WCs such as group stress, injuries, restriction of movement, resting problems and heat stress – all potentially leading to distress.

Due to a lack of available evidence from observations of pigs in transport over the relevant pig categories (weaners; finishers; and gilts, sows and boars combined), the allometric equation [$A = k \times W^{2/3}$] (where A is m^2 per animal, and W is liveweight in kg) can be used to estimate the minimum space allowances during transport of any category of pigs.

Among the five biological functions of space, room to physically fit into the compartment in a standing posture was taken as a starting point of the assessment.

The ability to maintain stability on moving vehicles was the second biological function of space. For pigs, however, almost no studies have been found to provide evidence within this area, and the available data does not allow sufficient conclusions. Research is required in this area.

The third biological function of space was resting in normal semi-recumbent posture. If the space allowance, driving conditions and vehicle flooring provide comfortable conditions, all categories of pigs will attempt to lie down to some extent along a journey. At some point in time, it becomes necessary for pigs to have space to lie down to reduce fatigue. The available evidence suggests that a k-value of at least 0.027 is required to provide the physical space for all pigs in a compartment to lie down simultaneously. There is evidence that provided with greater space, finisher pigs will lie down sooner on journeys, and lower skin damage occurs.

The fourth biological function of space is room to thermoregulate. According to the allometric calculations, a k-value of 0.047 is needed for pigs to be able to space out and lie in full lateral recumbency (producing no overlap or space sharing), but there is insufficient evidence identified to provide a specific quantitative information on the appropriate space allowance to thermoregulate under transport conditions.

For the fifth biological function of space, room to eat and drink, the tendency for pigs to develop motion sickness when fed just before a journey meant that in-transit feeding was not considered an option, and focus was given to the possibility to provide water during journeys. However, the current knowledge of the efficacy of water provision during transport of pigs is limited, and no research was identified to provide specific quantitative information on appropriate space allowances.

Regarding deck height, the available research is limited. Deck height is important for pigs of all categories to be able to stand freely, unhindered, to adjust their head and neck position, to allow pigs to manoeuvre inside vehicles, and also to allow sufficient flow of air around the pigs. A low deck height may lead to WCs such as injuries and increase susceptibility to heat stress. There are equations to estimate the height of pigs, but a lack of data to determine the appropriate deck height for different pig categories in order to protect their welfare during transport.

3.5.3.3. Thresholds for journey times

As previously mentioned in this Scientific Opinion and reviewed by Nielsen et al. (2011) and Cockram (2007), transport of animals is a complex stressor involving numerous aspects (related to the condition of the animals, their general biological characteristics, as well as the conditions under which the journeys take place including the duration), the majority of which to some extent may influence animal welfare. Despite the need for resulting recommendations and legislation, very few European studies have focused on the journey time (Faucitano and Lambooij, 2019).

Whether welfare issues arise during transport is not just dependent on the journey duration. In addition, there is not a linear relationship between journey duration and stress or animal welfare (Faucitano and Lambooij, 2019). Moreover, the journey duration, per se, is rarely the root cause of poor welfare, while other factors associated with time might lead to this result (Nielsen et al., 2011). It will depend upon multiple factors, including the category of pigs (e.g. age and condition), their fitness for transport, the quality of the journey (including vehicle design, space allowance, ventilation, the standard of driving and quality of the road), the microclimatic conditions and the associated handling and management of the pigs. When considering the implications of journey duration, it is important to consider the influence of each of the potential factors that can affect animal welfare.

Although quantitative limits often are included in legislation, there is no scientific consensus on: (a) the basis to be used to identify maximum journey durations; (b) what maximum journey durations should be specified; (c) what other factors should be considered when specifying a maximum journey duration; or (d) whether the current emphasis on using the intervals required to provide feed, water and rest is always the most appropriate way of specifying a limit on journey duration (Cockram, 2007).

In order to describe how the level of welfare develops over time during journeys, based on the above examination of the highly relevant WCs associated with the transit stage, the available research has been examined to identify what factors associated with transport have the potential to either increase or decrease the risk of WCs as a journey continues.

Cockram (2007) proposed that a rationale for a scientific justification of journey durations could be made based on one or more of the following criteria:

a) there are aspects of welfare that are negatively affected after a specific journey duration, and thus stopping a journey before this occurs would help to minimise these;
b) transported animals are exposed to continuous or periodic WCs, and restricting journey duration would minimise the duration of this exposure;

c) there are many risk factors associated with a specific form of transport that have the potential to negatively affect aspects of animal welfare; therefore, the risk that these will occur will increase the longer the journey takes to complete.

In this Scientific Opinion, the work carried out has been based on the approach suggested by Cockram (2007), involving the categorisation of highly relevant WCs for the transit stage into these three categories.

There are, however, several factors limiting this work: there have only been a limited number of studies that have investigated the effects of journey duration on the welfare of pigs, and the experiments available have often been often done using conditions that conform to what is considered best practice. For example, most studies were conducted in journey conditions that were close to or within the TNZ of pigs. As the quality of these journey conditions are likely to be high, and only fit and healthy animals were used, the results of many of these studies may not have identified major WCs associated with commercial journeys (as discussed by Cockram, 2007, 2019).

Multifactorial studies of commercial situations that apply epidemiological approaches to identify risk factors affecting specific outcomes, such as mortality or clinical deterioration, can sometimes identify a potential relationship between a WC as indicated by an ABM and journey duration (e.g. Thodberg et al., 2019), but often focus on rather extreme welfare end-points (such as dead-on-arrival (DOA), e.g. Malena et al., 2007) and not on the protection of animals from WCs. In this Scientific Opinion, signs of activation of coping mechanisms are taken as an indication of the presence of a hazard potentially leading to the corresponding WC.

The scenarios considered in this section refer to the transport of animals within the EU and take into account the recommendation made on microclimatic conditions (Section 3.5.3.1) and space requirements (Section 3.5.3.2). This means that the two WCs heat stress and restriction of movement are not considered highly relevant, and have not been part of the assessment.

The remaining highly relevant WCs during the transit stage are: motion stress, sensory overstimulation, group stress, injuries, prolonged hunger, prolonged thirst and resting problems. In addition, pain and/or discomfort associated with pre-existing or newly caused health conditions have been included. Below, the relationship between journey duration and these WCs are examined, ordered to align with the three different categories suggested by Cockram (2007): continuous or semi-continuous WCs, progressively developing WCs, and the more sporadic health conditions. Across studies underlying this assessment, it is important to consider in their interpretation whether the animals had limited access to water, and more restricted space allowance than permitted in EU legislation.

A) Motion stress and sensory overstimulation

Several studies involving transport of weaners or finisher pigs have found increased plasma concentrations of cortisol (Bradshaw et al., 1996a,b; Brown et al., 1999), which is an indicator of stress. For other pig categories, similar studies are not available or are very few.

The studies almost always only examined plasma concentration of cortisol before and after journeys, thereby involving many different WCs, and not describing the temporal relationship of the activity in the HPA-axis.

There are few studies available, where blood samples were taken during a journey, typically from catheterised animals. Bradshaw et al. (1996b) exposed 35-kg weaners to 8 h of being individually penned in a commercial pig truck, either stationary or while the truck was driven (Figure 10). Plasma cortisol increased rapidly after loading into the truck in both conditions, remaining elevated during the journey in the moving truck in comparison with the stationary treatment.

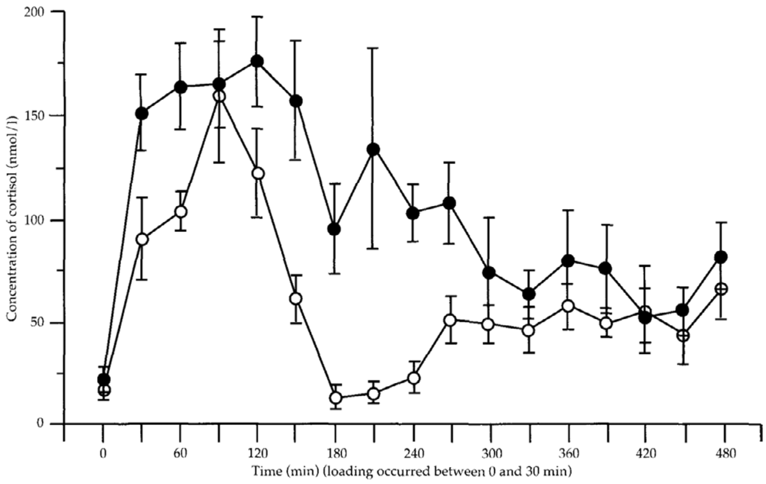


Figure 10: Plasma cortisol in 35-kg pigs (N = 6) kept for 8 h individually penned in a commercial pig truck, either stationary (open circles) or moving (closed circles) (Bradshaw et al., 1996b)

Bradshaw et al. (1996a) transported pigs over 2 days and found higher cortisol responses on the first compared to the second day, emphasising that also aspects of novelty influence the stress responses of pigs to being transported.

Pigs transported by road have been shown to exhibit motion sickness-related behaviours, such as foaming, chomping, retching and vomiting, along with increase in plasma lysine vasopressin (Bradshaw et al., 1996a,b, 1999; Randall and Bradshaw, 1998; Santurtun and Phillips, 2015). Consequently, it has been suggested that pigs are more vulnerable to motion stress than many other species transported for commercial purposes. No studies relating journey duration to the occurrence of motion sickness in pigs have been found.

During transport, pigs are exposed to vertical, lateral, and horizontal vibrations (See Section 3.5.2 [motion stress and sensory overstimulation]). Unpaved roads or roads with strong wind currents transmit a more significant amount of vibrations. Pigs' reaction to transport has been shown to be affected by road type: rough journeys result in higher cortisol elevations. Bradshaw et al. (1996a) transported pigs of 40 kg for 100 min on rough vs smooth roads and took blood samples via jugular catheters every 20 min (Figure 11). However, since the rough part of the journey was also the initial phase, the difference between the response in plasma concentration of cortisol between the two types of road may be confounded by time or novelty.

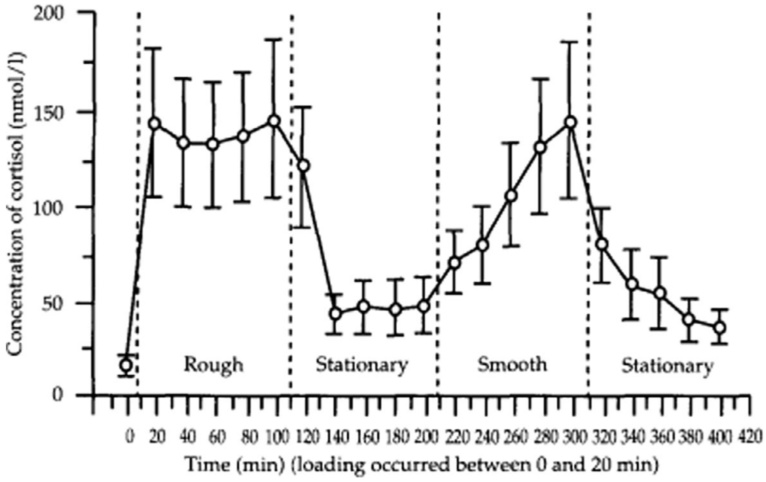


Figure 11: Plasma cortisol (nmol/L) in 40-kg pigs transported on rough vs smooth roads for 100 min, respectively. The pigs were blood sampled every 20 min by use of catheters (Bradshaw et al., 1996a)

Driving quality (e.g. speed) and conditions (e.g. poor roads, wind and precipitations) have been also positively associated to increased animal losses, carcass bruising, leg fractures, blood CK concentrations (indicator of fatigue) at slaughter and frequency of pale, soft and exudative meat (Dalla Costa et al., 2019; Passafaro et al., 2019; Zou et al., 2020; Driessen et al., 2020a,b; Romero et al., 2022).

Vibration associated with transport has been demonstrated to be aversive to pigs. Stephens et al. (1985) taught pigs to press a switch panel to turn off a transport simulator which produced noise and vibration. When the vibration component was switched off, pigs continued to switch the noise component off, though with a lower frequency, which indicates a greater aversiveness to vibrations than to sound. All pigs responded behaviourally to terminate the simulator. During the series of studies, pigs were always exposed to 1 h of simulations, thereby not providing evidence on the any temporal association between vibrations and aversion.

B) Group stress and injuries

Group stress is a highly relevant WC for pigs during the transit stage. Injuries in the form of skin lesions (scratches and wounds) are often the physical outcome of group stress in pigs, and therefore these two WCs are combined here.

When pigs are mixed, it is part of their natural behaviour to establish a new social hierarchy. This is done by social behaviour of which aggressive behaviours and fights are a central component, and may go on for days (Turner et al., 2006b; Fabrega et al., 2013). As described in Section 3.3, during pig transport, pigs are typically mixed at least once during the hours preceding the journey, and also often mixed at loading as vehicle compartment size and the size of home pens or 'pick-up' pens or other facilities are often not matched. This practice constitutes a hazard for animal welfare, and means that pigs will be exposed to the WC group stress during most journeys, except for boars, that are typically transported in single compartments.

Only a few studies have quantified pig behaviour during journeys, and even fewer have compared pigs that are mixed vs non-mixed in order to quantify group stress during journeys. In addition, almost all of the available studies involve finishers even though weaners (Magnani et al., 2014) and sows (Herskin et al., 2017) will also fight when mixed.

Gerritzen et al. (2013) transported finishers of ~ 110 kg on four 550 km journeys at each of two stocking densities (230 or 179 kg/m^2), all fasted for 8 h pre-transport. Fighting occurred during all journeys. Most fights were observed at loading, in the first 2 h after departure and immediately following the driver's break after ~ 4 h of transport (Figure 12).

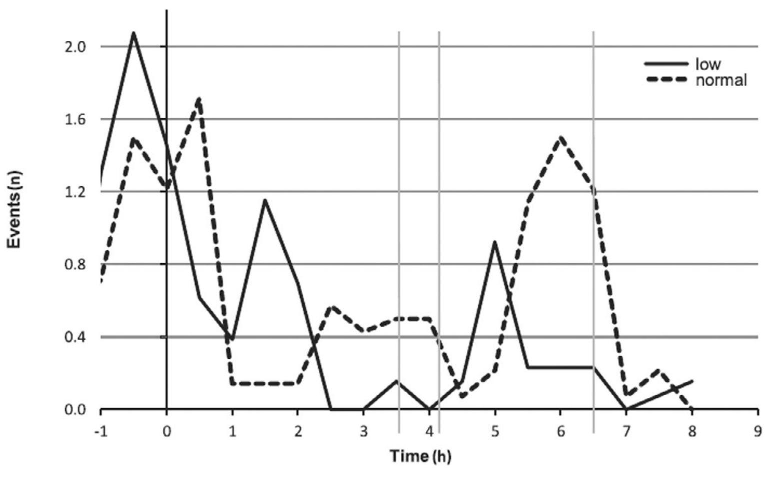


Figure 12: Number of fighting events recorded during 4 journeys transporting finishers at each of two stocking densities (230 or 179 kg/m^2), all fasted for 8 h pre-transport. A 45-min driver break was held after ~ 4 h (Gerritzen et al., 2013)

Bradshaw et al. (1996b) transported 90-kg pigs (N = 12) to slaughter in a commercial pig truck, with a journey duration of 1.5 h. At loading, the pigs were either kept with pen-mates or mixed with unfamiliar pigs. During journeys with unfamiliar pigs, the pigs showed increased activity and increased fighting. The pigs were sampled for saliva cortisol before, in the middle of the journey and upon arrival. For pigs transported with pen-mates, the saliva concentration of cortisol increased throughout the journey. Pigs transported with unfamiliar individuals showed higher saliva cortisol concentrations as compared to the familiar treatment in the middle of the journey, at the end, and after the journey (Figure 13). Thus, being transported with unfamiliar conspecifics is more stressful to pigs than transport with familiar individuals. However, no studies to describe the development of group stress or injuries in relation to journey time have been found.

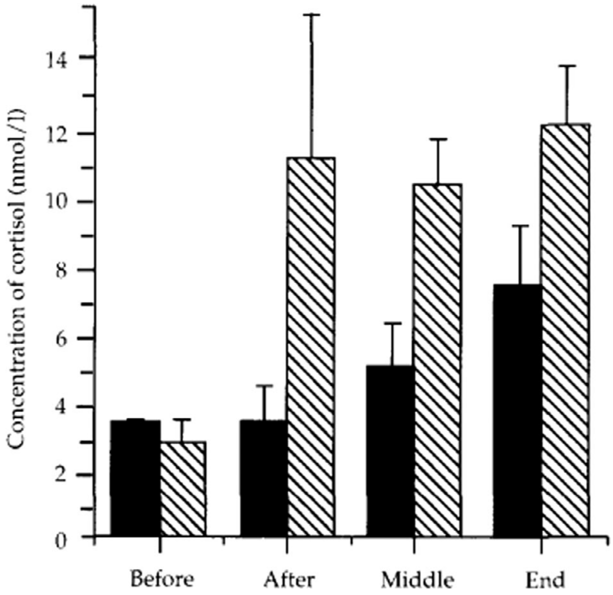


Figure 13: Plasma concentration of cortisol in 90-kg pigs transported 1.5 h to slaughter either with pen-mates (dark bars) or when mixed with unfamiliar pigs (hatched bars) (Bradshaw et al., 1996b)

C) Prolonged hunger

Despite the existence of motivational tools to use in farm animals, including operant techniques (e.g. Jensen et al., 2015) to quantify affective states, such as hunger, these approaches have not been applied to transport conditions. In studies of the welfare implications of transport, carried out without access to feed, emphasis has been placed on physiological measurements that indicate a mobilisation of body energy reserves by monitoring peripheral blood concentrations of metabolites, as well as tissue concentrations of energy reserves, e.g. liver glycogen concentrations. Some studies have included post-transport measurements of feed intake, which are easier to interpret in terms of motivation. However, across transport-related studies involving either physiological indicators of hunger or measures of feed intake, the level of hunger has been assessed before and after journeys, and no studies to describe the development of hunger in relation to journey time have been found.

Due to the tendency for pigs to develop motion sickness (Randall and Bradshaw, 1998; Santurtun and Phillips, 2015), as described in Section 3.5), as well as the requirement for pre-slaughter fasting (EFSA AHAW Panel, 2020), most pigs are fasted before the initiation of journeys.

In his review of pig welfare during transport, Warriss et al. (1998) estimated a rate of loss in body weight of ~ 0.2% of liveweight per hour. Part of this body weight loss was due to the urination and excretion during transport. Indications of loss of body reserves started 9 h after the last meal with the reduction of carcass weight and 18 h after last meal for the liver weight loss. Associated with the liver weight loss is a reduction in liver glycogen content. This follows a logarithmic pattern (Warriss and Bevis, 1987), so that very little remains after 24 h, over 2/3 having been lost in the initial 12 h. According to Warriss et al. (1998), it is likely that pigs are feeling very hungry at this time.

Driessen et al. (2020) stated that to estimate the total fasting time, time without feed on-farm, loading time, transport time, unloading time, and time in lairage (for animals sent to slaughter) must be taken into account. To determine the start of fasting, one should start from the estimated moment of slaughter, or arrival for further fattening, and then work backwards to determine the duration to determine the start of the fasting period. In the final publication from the EU Transport Guides Project (Consortium on the Animal Transport Guidelines Project, 2017), it was recommended to differentiate pre-transport fasting time depending on the expected duration of the future journey. The authors recommended to fast finishers and cull sows/boars for a minimum of 10–12 h before the animals are loaded onto the vehicle, if the expected journey duration is less than 8 h, and to fast them on-farm for a minimum of 5 h if the journey duration is expected to exceed 8 h. For pigs transported for further fattening, the authors recommended minimum 5 h of on-farm fasting in preparation of all journeys. No scientific evidence underlying these recommendations is provided, and no maximum fasting time recommendations were given.

To the best of our knowledge, no recent studies have identified pros and cons of pre-journey fasting, examined effects of fasting duration or established guidelines, for example taking into account different types of feed (wet feed vs dry feed fed from feed stations) in pigs transported for further fattening. Such knowledge would be valuable for the assessment of WCs including prolonged hunger and aggression as a consequence of hunger. Another potential WC of prolonged fasting, especially relevant for pigs not destined for slaughter, is the development of gastric ulcers. As reviewed by Driessen et al. (2020), earlier studies have suggested a positive relationship between overnight fasting and the occurrence of gastric ulcers at slaughter, but there are also studies failing to find an effect of fasting time on the prevalence of gastric ulcers (Eisemann et al., 2002; Dalla Costa et al., 2008). Whether the duration of pre-journey fasting influences the risk of development of gastric ulcers in pigs transported for further fattening is not known but cannot be excluded.

D) Prolonged thirst

Thirst is a sensation that motivates animals to seek and drink water to maintain homeostasis (McKinley and Johnson, 2004). If thirst is severe and prolonged, it can be associated with dehydration and weakness. Physiologically, thirst is initiated by an increase in the osmolality of body fluids and by a decrease in body fluid volume (De Araujo et al., 2003). Receptors detect the increased osmolality and decreased extracellular volume and stimulate activation of physiological homeostatic mechanisms to conserve body water and promote thirst to motivate the animals to drink (McKinley and Johnson, 2004).

The WC prolonged thirst describes a situation where an animal experiences a craving or urgent need for water, accompanied by an uneasy sensation (a negative affective state), and eventually leading to dehydration as metabolic requirements are not met. If access to water is limited, or prevented, then a significant and prolonged increase in the motivation to drink may result, the thwarting of which may be associated with a negative subjective experience of thirst (Fraser and Duncan, 1998; Jensen and Vestergaard, 2021).

In a study of lactating sows, kept loose-housed, Jensen et al. (2016) showed that behavioural signs of thirst increase with increasing duration of water deprivation (from 0 to 12 h of over-night deprivation. Based on observations of a post-deprivation reduced latency to drink and an increased compensatory water intake, the authors suggested that these behaviours were associated with a negative subjective experience of thirst. This suggestion was supported by observations of behaviour indicative of frustration and restlessness, such as sniffing and forcefully manipulating the water trough before it was opened, and reduced lying and inactivity during the 30 min before trough opening. These behaviours were mainly seen in sows deprived for water for 6 or 12 h. However, only a few studies have examined the intake of water during pig transport.

When water is available on the vehicle, there is evidence that pigs use drinkers during the journey, however, it is not clear how much is consumed vs. wasted. Frotin et al. (2002) determined the quantity of water disappearance by finishing pigs during a 24-h journey according to three types of watering (trough/nipples/bowl). The average water use (as assessed by water flow meter every 4 h of transport) varied between 2.4 and 4.5 L/pig, with more than 80% of water use during the transit stage (compared with stops) and greater use during the first half of the journey. Chevillon et al. (2003) reported that larger volumes of water were used when finishers were transported as compared to pigs staying on-farm, but did not quantify the water intake of the pigs, and reported significant spilling. In two studies involving finishers (Lambooij, 1983; Lambooij et al., 1985) showed that pigs drank only very small volumes of water during transport. In journeys of 26–31 h, pigs consumed an average of 0.65 L/pig (Lambooij, 1983). Finisher pigs transported for 44 h (the journey duration included several short stops, and one stop of a longer duration on the second day of the journey) with water provision used very little water (5.4 L/pig), and were observed to waste water by leaning on the nipple drinkers (Lambooij et al., 1985). Comparing their findings to a predicted normal water consumption of 7–20 L/day (Warriss, 1998), the authors concluded that provision of water drinkers onboard vehicles is not effective.

More recently, Gerritzen et al. (2013) reported that finishers of 110 kg used 0.9 L water/pig during a 550 km journey lasting almost 8 h. Whether the water was consumed or wasted, was not reported, and no clear change in water use from when the vehicle was stationary to when it was in transit, was observed. For weaners, transported for 14 h with water provision, no on-board drinking behaviour was observed (Magnani et al., 2014). When water was continuously available to weaners transported for 23 h, and water wastage was scored from pictures (as in Figure 14), the level of water wastage seemed to be quite variable between trips and between truck compartments (Cecilie Kobek-Kjeldager, Aarhus University, personal communication).

Figure 14: Picture taken after unloading of weaners of 20–25 kg transported at 0.18 m^2/20 kg for 23 h as part of an experimental study in Denmark. The nipple drinker is marked on the picture, and water was continuously available. On some trips, and in some compartments, water wastage led to pools of water, despite the ample amount of bedding used. Photo: Cecilie Kobek-Kjeldager, Aarhus University

The provision of water on-board vehicles is, thus, an area that requires further study, in particular to determine if drinker use and water consumption occurs, to determine the appropriate pig to drinker ratio, and location of drinkers on board vehicles transporting pigs. Due to the lack of documentation for the efficacy of water provision on-board vehicles transporting pigs, the present assessment of the relationship between the WC prolonged thirst and journey duration, is not split into vehicles with or without drinkers.

The capacity of pigs and other non-ruminant livestock to respond to water deprivation is low (as reviewed by Vogel et al., 2019). Warriss et al. (1983) reported increased water consumption in lairage for pigs transported for 6 h compared with animals transported only 1 h. Brown et al. (1999) evaluated the effect of 8, 16 and 24 h of transport (without stops and water availability) in pigs of 80–100 kg. Total protein and albumin levels increased progressively, but differences were only significant after 24 h. The authors concluded that dehydration developed gradually. When observing the behaviour of the pigs during a 6-h lairage period after unloading, all three journey durations led to temporal patterns of drinking behaviour, involving what seemed to be giving higher priority to drinking instead of resting or exploring, the longer the journey the pigs had experienced. In addition, water intake in lairage was higher for pigs transported 24 h than for the two other journey durations.

Becerril-Herrera et al. (2010) transported gilts and barrows to slaughter in Mexico by use of commercial trucks. The authors did not report pig weight, ambient temperatures, level of pre-transport fasting, road conditions or space allowance. The pigs did not have access to feed or water during journeys of either 8 or 16 h. Based on quantification of haematocrit from blood samples taken before and after the journeys, the authors concluded that signs of dehydration were present for both journey durations.

Goumon et al. (2013b) studied the effect of 6, 12 and 18 h of transport and of vehicle compartment on the physiology and behaviour of pigs in summer and winter in western Canada, and highlighted that, at the lairage, drinking behaviour did not differ between transport duration treatments in summer, while in winter, pigs from the 18 h treatment drank more than pigs that were transported 6 or 12 h, thus showing greater evidence of thirst.

E) Resting problems

Irrespective of the space provided for the animals, the movement of a vehicle obliges pigs to make continuous postural adjustment to acceleration changes, in order to maintain their balance and avoid falling. In addition, when pigs are mixed at or before loading, in some animals, the motivation to rest may be thwarted by other animals fighting in the compartment or by disturbance from attacking individuals. Thus, even if the space allowance is large enough for pigs to lie down during journeys, they may still experience the WC resting problems, potentially leading to fatigue or to pigs being non-ambulatory – a condition not uncommon in pigs upon arrival at slaughterhouses, at least in some geographical regions (as discussed by Garcia et al. (2019)). Fatigued pigs are pigs without obvious injury or disease showing signs of severe acute stress that result from exhaustion.

As mentioned in Section 3.5.3.2, studies of behaviour of finishers during transport have shown that during short (2 h) journeys, pigs spend a numerically greater proportion of observations standing (mean: 46%), than lying (8%), (Torrey et al., 2013a). On longer journeys (8 h), pigs have been observed lying for a numerically greater proportion of observations (lying: 52% vs. standing: 16%) (Torrey et al., 2013b).

Brown et al. (1999) evaluated the effect of 8, 16 and 24 h transport (without stops and water availability) in pigs of 80–100 kg, transported at space allowance of 0.50–0.54 m^2/100 kg. When observing the behaviour of the pigs during a 6 h lairage period after unloading, the authors stated that the pigs seemed tired, however without direct quantification thereof. Gerritzen et al. (2013) transported finishers of ~ 110 kg on four 550 km journeys at each of two stocking densities (230 or 179 kg/m^2), all fasted for 8 h pre-transport. The authors observed that, during the driver break (45 min of stationary vehicle, 4:15 h after the start of the journey), up to 80% of the pigs were recumbent, irrespective of loading density. The authors considered such an urge to lie down as an indication of a motivation to rest, which was presumably restricted when the vehicle was moving.

Blood and tissue measurements indicative of exhaustion of body energy reserves (e.g. hypoglycaemia and reduced liver and muscle glycogen concentration) and the accumulation of metabolites, e.g. blood and muscle lactate concentration (Frese et al., 2016) in response to prolonged and anaerobic exercise, might be associated with fatigue (Terlouw and Bourguet, 2022). Yu et al. (2009) reported increased blood plasma CK and LDH levels after transport of finishers for 1, 2 or 4 h, respectively. The longest journeys were associated with increased serum CK activity.

The effects of journey duration on the welfare of pigs were investigated by Aradom et al. (2012) in journeys lasting 4, 8, or 12 h, during two seasons. In their study, involving pigs of 100 kg, transported at 0.55 m^2/pig, a continuous increase in serum CK was associated with the prolonged journeys, suggesting increasing muscular fatigue with longer journey time (Figure 15).

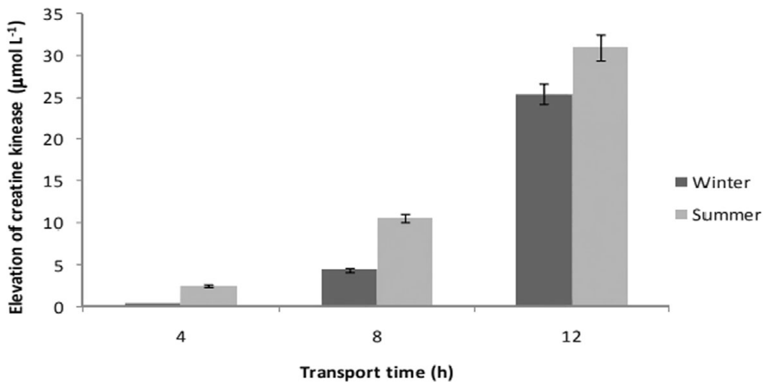


Figure 15: Changes in plasma concentration of creatine kinase (CK) in finishers transported 4, 8 or 12 h during summer and winter, and blood sampled before and after the journey (Aradom et al., 2012)

In a study from Western Canada, Sommavilla et al. (2017) transported finishers at ~ 0.37 m^2/100 kg in pot-belly trailers, and studied the effects of the season and journey duration (6, 12 or 18 h), and found that blood CK was greater in pigs after 18 h of transport, showing a linear increase with the increasing transport time.

Among the available pig studies, the majority have focused on non-ambulatory pigs as a sign of fatigue. The vast majority of the available studies are from North or South America, and there are examples of surveys suggesting that relatively short journey times (30 min to 4 h) was one of the factors influencing the risk of non-ambulatory pigs (Sutherland et al., 2009), but also studies finding no effect of journey time (comparing < 1 vs. 3 h) on the prevalence of non-ambulatory pigs (Pilcher et al., 2011). In an observational study involving more than 300 loads of finishers shipped from 60 farms to three different slaughter plants, where the prevalence of non-ambulatory pigs was reported to be 0.37%, Dalla Costa et al. (2019) showed that the probability of becoming non-ambulatory was greater for every additional hour that the pigs spent during transport.

F) Summary on journey duration

Regardless of how optimal the conditions of the journey provided are, pigs can potentially be exposed to a number of hazards during transport that might, either on their own or in combination, result in impaired animal welfare. The amount of time the animals are exposed to these hazards is dependent on the journey duration. Any aversive effects of resting problems, or reduced availability of, or restricted access to water and feed, are likely to increase with journey duration and could interact with other factors, such as temperature, that might also change during a journey.

Above, the available research has been appraised to identify relationships between journey duration and highly relevant WCs. The information is summarised below. Based on estimates of risk, the prevalence and severity of the WCs, a table (Table 26) has been created to show the estimated journey duration after which the WCs are expected to be present. The assessment of journey duration takes as a starting point that recommendations on microclimatic conditions and space allowance are followed.

Summary – motion stress and sensory overstimulation: As soon as a vehicle starts moving, and during all time when it is moving, all pigs are to some extent exposed to motion stress, and often also, at least periodically (repeated intermittent), to sensory overstimulation. As a consequence of the vehicle motion, animals experience stress potentially leading to fatigue and other negative affective states such as fear and distress, due to the forces exerted as a result of acceleration, braking, stopping, cornering, gear changing, vibrations and uneven road surface. Motion stress is regarded as a highly relevant WC in the transit stage. The prevalence is high, as motion stress is likely to affect all animals in a moving vehicle. The duration of the WCs depends on journey duration and onset of vehicle motion. For pigs, the tendency to develop motion sickness means that this WC is a major consideration. Motion stress will vary over time depending on the journey conditions, but the severity of its effects will most likely increase over time and may eventually lead to fatigue. Based on the constant presence of motion stress, it is not possible to estimate a temporal cut-off for onset of this WC after initiation of the transit stage.

Summary – group stress and injuries: Group stress and resultant injuries (skin lesions) are regarded as a highly relevant WC in the transit stage for pigs exposed to the hazard of mixing at any pre-journey stage. The prevalence is high, as mixing is industry practice. Group stress likely affects all animals in a moving vehicle, however with a variation in severity, as not all pigs will be involved in fighting to the same extent. The duration of group stress depends on journey duration, but the temporal development is not known. Severity is expected to increase with increasing duration, as the lack of resting (in fighting animals, and animals being disturbed by other animals fighting) may become problematic for the animals. Group stress may lead to fatigue. No studies to describe the development of group stress or injuries in relation to journey duration have been found.

Summary – prolonged hunger: The WC prolonged hunger is regarded as highly relevant in the transit stage. The prevalence is expected to be very high, as pigs – especially animals sent for slaughter – likely have been fasted before the initiation of the journey. The severity of hunger will develop further during the journey. The duration of hunger depends on fasting practices, journey duration and availability of feed in transit, and severity is expected to increase with increasing duration, as the need for feed becomes more problematic for the animals. Prolonged hunger may lead to frustration, exhaustion and a weakened condition. The available data does not allow a detailed determination of the interval between journey start and initiation of prolonged hunger. Based on the available knowledge on physiological indicators of hunger (e.g. liver glycogen) as well as behavioural studies of post-journey eating behaviour, hunger is expected to be present after 12 h of feed deprivation, which (under current practice), for a large proportion of pigs transported to slaughter, corresponds to the initiation of the journey.

Summary – prolonged thirst: The WC prolonged thirst is regarded as highly relevant in the transit stage. The prevalence may be high, if water is not provided to the animals or they, for some reason (such as lack of familiarity or fear of other animals) are not able to obtain enough water. So far, very limited documentation for proper intake of water, even in journeys fitted with drinkers, is available. Depending on factors such as time off water before journey start and/or microclimatic conditions before and during the journey, pigs may not be thirsty during the initial phase of the journey, but thirst will develop over time if water is not freely accessible. The duration of prolonged thirst depends on accessibility of water and journey duration, and severity is expected to increase with increasing duration, as the need for water becomes problematic for the animals. Prolonged thirst may lead to dehydration, frustration, discomfort and suffering. The available data does not allow a detailed determination of the interval between journey start and initiation of prolonged thirst. Based on the available knowledge, it is possible that the increase in total plasma protein concentration (indicative of a reduction in plasma volume) as well as behavioural changes seen in some studies within 8 h without water might be associated with thirst, whereas for example lactating sows most probably are thirsty after a shorter interval.

Summary – resting problems: Resting problems are regarded as a highly relevant WC in the transit stage. The prevalence is at least moderate, as resting problems may affect a large proportion of animals in a moving vehicle, even when space for lying is available. Duration depends on journey duration, and severity is expected to increase with increasing duration, as the lack of resting becomes problematic for the animals. Resting problems may lead to fatigue. Irrespective of the space provided, resting problems may arise due to exposure to vehicle motion, as well as associated with the consequences of group stress – the participation in fighting or the disturbance from fighting conspecifics. Based on the constant presence of motion stress, it is not possible to estimate a temporal cut-off for onset of this WC after initiation of the transit stage.

Other summarising considerations: In addition to the WCs summarised above, the risk of pigs experiencing pain and/or discomfort, as well as the severity of it, will also increase with journey time. This may happen if a pig has a pre-existing, but non-identified, painful condition. Even though this should not happen, it is not always possible to identify pathological conditions in pigs while they are on-farm, that could subsequently affect their ability to respond to transport (as surveyed by Herskin et al. (2020) and Thodberg et al. (2020) among sow farmers and livestock drivers, respectively).

In addition, pigs which did not show a health condition before the journey may get injured during the journey due to, for example aggressive behaviour, and the pain and discomfort from such conditions will continue, and likely worsen, until the animal can be unloaded. In this weakened state, pigs may be less able to cope with the challenges associated with transport, and their condition may deteriorate with time and journey duration (as shown for cull sows in Denmark after journeys up to 8 h (Thodberg et al., 2019)).

The pain and/or discomfort from both types of the above-mentioned health conditions are not expected to be prevalent, but for the affected animals, the consequences may be severe, and will often develop over time. The duration of these negative affective states will depend on journey duration, as they cannot be terminated until the journey is stopped (or sometimes not until post-transport healing). During a journey, such health conditions may lead to suffering. It is, however, not possible to establish a temporal cut-off for when pain and/or discomfort may start.

Among the available studies of welfare of pigs during transport, many have focused on pigs dying in transit. Pigs dying in transit most likely experience negative WCs during their last hours alive. In Italian and German epidemiological studies, journey duration (more than 2 h journeys in summer, and more than 8 h journeys in winter) contributed to increased mortality rate (Werner et al., 2007; Vitali et al., 2014).

Outside Europe, information on the effects of journey duration on pig mortality is available from the USA and South America. Similar to the effects of journey duration on non-ambulatory pigs, some studies found shorter journeys to be one factor increasing the incidence of mortality (Sutherland et al., 2009). However, in a survey carried out on about 40,000 pigs, Kephart et al. (2010) found no effect of journey time on rates of mortality (0.06%) after transport to a packing plant comparing two journey durations (< 2.5 h vs. ≥2.5 h; ranging from 1 to 14.5 h). Similarly, Pilcher et al. (2011), examining effects of journey duration (< 1 h vs. 3 h) and floor space on the prevalence of transport losses found no effect of either journey duration or floor space on the mortality. There are, however, also studies showing positive relationships between the occurrence of dead-on-arrival and journey duration (e.g. Dalla Costa et al., 2019; Romero et al., 2022).

Table 26 summarises the estimated interval from journey initiation and until presence of the highly relevant WCs.

Table 26: Welfare consequences estimated to start and develop over journey time

Type of welfare consequence	Welfare consequence	Development over time	Expected development over time
Continuous or semi-continuous	Motion stress	Continuing throughout the transit stage	Severity will increase over time leading to fatigue
	Sensory overstimulation	Sensory overstimulation repeated intermittent	Can lead to fear and distress
	Group stress and resultant injuries (skin lesions)	Continuing throughout the transit stage, but development over time not known	Group stress may lead to fatigue, injuries will lead to pain and/or discomfort.
	Resting problems	Continuous throughout the transit stage	Severity will increase over time leading to fatigue
Progressively developing	Prolonged thirst	Available information shows that behavioural and physiological signs of thirst can be present after 8 h of transport without effectively accessing water.	Severity will increase with time, leading to dehydration
	Prolonged hunger	Available information shows that behavioural and physiological signs of hunger can be present after 12 h of feed deprivation. Depending on the pre-transport fasting this may correspond with initiation of the journey.	Severity will increase with time, leading to weakening and exhaustion
Sporadic	Pain and/or discomfort from health conditions	May start at any time if pre-existing health conditions are present or occur during transport	If present, severity will increase with time, leading to suffering

3.6. Journey breaks

At some stage during a journey, pigs will need feed, water and rest in order to avoid WCs. This can be done in two ways: (1) by providing the animals with feed, water and rest while the truck is stationary; and (2) by unloading the animals and providing them with feed, water and rest there (at a CP). Below, the different possibilities are discussed, and hazards, WCs, preventive and corrective/mitigating measures are assessed for the use of CPs.

3.6.1. Provision of water and/or feed on the vehicle while stationary

Regarding provision of feed, the tendency for pigs to develop motion sickness (Randall and Bradshaw, 1998; Santurtun and Phillips, 2015), as described in Section 3.5.2, means that provision of feed to pigs on stationary vehicles during breaks in driving, likely will be difficult, as the journey probably cannot be continued until hours after the feeding of the animals. Research is needed to clarify costs and benefits of such practice.

3.6.2. Unloading of the pigs into a pen where water and/or feed is provided for a period of time before reloaded to continue the journey

Theoretically, unloading pigs into a pen allows the animals to have access to resting, watering and feeding areas in order to mitigate the WCs of transport. However, stopping a journey to unload the animals to provide a period of rest, feed, and water involves a number of hazards relevant for animal welfare such as the risk of stress, injury and infectious diseases. Some of these can be mitigated by the duration of the stay, some by offering high quality conditions to the animals, whereas others, such as the novelty of the surroundings, the extra unloading and reloading, and the mixing of unfamiliar animals as well as the inherent biosecurity risk, cannot be avoided. Thus, whether there are always beneficial effects for the welfare of pigs for a long journey to be interrupted to offer feed and water while unloaded is equivocal.

However, as most research involving long journeys for pigs have been carried out in North America, where journeys are typically not interrupted, the available knowledge in this field relating interruptions in long journeys with the welfare of pigs, is very limited. This limits the possibility to reach conclusions and recommendations. Below, the current knowledge and use of CPs to unload pigs during long journeys are discussed.

3.6.3. Control posts

CPs are specialised livestock facilities, usually private, where animals can be offered a journey break after reaching the maximum journey time. Currently, a stay in a CP has to be 24 h before the journey can be continued. The CPs are used exclusively for receiving, feeding, watering, resting, housing, caring for and dispatching transient animals. The operators of CPs are obliged to ensure that the animals receive the necessary care, feed and water, and before animals leave a CP, an official veterinarian must verify that they are fit to continue their journey (Schmid and Kilchsperger, 2010). Also, CPs typically offer facilities for vehicles, drivers and competent authorities. In this Scientific Opinion, the section on CPs includes all kinds of actions and management of the animals, which take place during the interval from when the animals have been unloaded from the vehicle, and until reloading is started to continue the onward journey. Loading and unloading are covered in Section 3.4. For management, planning and logistics issues, readers are advised to consult the recommendations of the EU Transport Guidelines (Consortium of the Animal Transport Guides Project, 2017).

Two EU projects were funded by DG Sante of the European Commission to renovate and promote high quality CPs in the EU and to develop an EU-wide animal transport certification system. The first project 'Renovation and promoting high quality control posts in the European Union' was concluded in September 2013, while the second initiative 'Development of an EU wide animal transport certification system and renovation of control posts in the European Union' was concluded in 2015. Both projects showed that many CPs had problems to be financially profitable and needed rebuilding or renovating to reach high quality standards. To the best of our knowledge, newer data on CP standards are not available. In this Scientific Opinion, the recommendations from the projects are referred to as Porcelluzzi (2013), but it is important to bear in mind that this is not a reference to a scientific study.

The photo below is taken from an anonymous CP in France, but it is not known whether or not the conditions observed there are representative for the standard of pig CPs across (or outside) EU (Figure 16).

Figure 16: Photo taken at anonymous control post authorised for pigs in France. The pigs are 20- to 25-kg weaners transported on a journey from Denmark. Photo: Mette S. Herskin, Aarhus University

Porcelluzzi (2013) stated that a resting period in a CP is the most appropriate solution to the challenges of long journeys in terms of animal welfare, because the animals are supposed to be getting adequate rest, feed and water, according to their needs, and to access comfortable bedding areas, as well as feeding and watering resources. Based on this, the authors of the report concluded that the use of CPs is an efficient means to improve animal welfare. However, as mentioned by Padalino et al. (2018), this conclusion does not seem to be supported by scientific data, as currently very limited studies on cattle welfare at CPs in the EU are available.

Irrespective of the duration of the stay, a stay in a CP may involve several hazards for animal welfare. Whether the WCs of the use of CPs are increased by successive stays (during very long journeys where pigs are unloaded for rest more than once) has not been examined but cannot be excluded. In this chapter, the main focus is on WCs, their hazards, recommendations to prevent hazards, as well as to mitigate WCs connected to the stay at a CP. In Section 3.8 (Specific scenarios: Special Health Status), potential WCs from omitting CPs and letting pigs be fed, watered and rested on the vehicle as an alternative, are discussed.

The text of this chapter focuses on weaners sent for further fattening, and to a lesser extent young boars or gilts transported for breeding, as these are the main pig categories currently experiencing journeys with rest stops. Other pig categories are mentioned briefly when relevant.

3.6.3.1. Current practice

According to the list retrieved from https://www.pvd.gov.lv/lv/media/539/download in January 2022, there were 62 CPs for pigs on the EU approved list. CPs are distributed unevenly across MSs, and few countries (e.g. Germany, Italy, Poland, Ireland and France) host the majority of them. No list of approved CPs outside the EU exists, which has been described as a concern for competent authorities, as they may have difficulty to verify whether the place outside the EU, where animals are planned to stop to be unloaded, has suitable conditions for this.

3.6.3.2. Highly relevant welfare consequences

The highly relevant WCs are: group stress, handling stress, heat stress, injuries, prolonged hunger, prolonged thirst, resting problems and restriction of movement. The WCs and associated hazards are explained below. The presence and severity of these WCs depend on the management (e.g. cleaning and disinfection procedures, availability of reservation system), the housing conditions (type of barn, ventilation, bedding, etc.), the equipment (e.g. ramps to (un)load, drinkers, feeders) and training of the staff at the CP. In addition to the WCs listed above, another welfare hazards related to the use of CPs are animals developing health conditions or becoming unfit for further transport. Below, this hazard is listed together with other welfare hazards associated with the different WCs. In addition, preventive and corrective/mitigating measures are listed.

i) Group stress and injuries

Group stress is a highly relevant WC for pigs in a CP. Injuries in the form of skin lesions (scratches and wounds) are often the physical outcome of group stress in pigs, and therefore these two WCs are combined here. The main hazards for group stress and injuries are:

Mixing unfamiliar animals: Due to the biology of pigs, mixing will unavoidably lead to aggression and fighting, which may impair animal welfare and lead to another WC, injuries, in terms of skin lesions. In addition, taking part in fighting prevents pigs from resting, and the presence of fighting individuals in a pen can limits the possibility of pen-mates to acquire the rest that they need.

- PRE: In the European handbook (Porcelluzzi, 2013), it is recommended that CP pens are divided so that animals can be kept in the same groups as in the vehicle, and thus avoid mixing. For pigs, however, the group size in vehicles is likely often lower than the group size in CP pens, and mixing is probably difficult to avoid with the current CP layout. Therefore, a larger space allowance is recommended in CP pens than during on-farm conditions.

Limited resources: In general, the consequences of fighting in terms of welfare are increased when resources are limited. After many hours in a vehicle, pigs arriving in a CP will be hungry (although neither weight loss nor feeding motivation have been quantified in CPs so far), and likely also thirsty. The presence of fighting pen-mates may limit the access of themselves as well as other pigs to the resources. In addition, limited resources, e.g. fewer eating places than pigs, and too few drinkers, may increase the likelihood of aggression.

- PRE: Feed and water should be available in adequate quantities and homogenously distributed to avoid fighting for resources. In addition, the presence of bedding and/or other materials to attract the exploratory motivation of pigs may inhibit or delay aggression. However, these effects have not been documented in CPs.

Corrective/mitigating measures of group stress

If signs of group stress, such as aggression, are observed in the CP, animals from different groups should be separated as much as possible, to allow a proper rest. In addition, enrichment (e.g. straw) may be provided to distract the pigs.

ii) Handling stress

Handling stress is a highly relevant WC in CPs. The hazards contributing to handling stress (i.e. inappropriate handling), preventive and mitigation measures are identical to the ones previously described in the preparation and loading/unloading phase (Sections 3.3 and 3.4).

iii) Heat stress

As reviewed in Section 3.5.3.1, pigs are sensitive to heat stress. The European handbook (Porcelluzzi, 2013) recommends that pigs at CPs are always kept in their TCZ. See Section 3.5.3.1 for recommendations on TCZs for the pig categories typically transported via CPs. The main hazard for heat stress at a CP is:

High/low temperature in the CP: If CPs are not equipped with proper ventilation and temperature control, there is a risk (however unquantified) that pigs will experience heat stress while kept in the CP pen. During winter months, there is also a risk that the animals may experience cold stress. For animals arriving from a vehicle, where it can also be difficult to keep the microclimatic conditions in the recommended comfort zone, the risk for WCs is likely higher than during periods where the outdoor temperature allows pigs to be transported within their TCZ.

- PRE: To prevent this hazard, pigs should be transported in their TCZ, as explained above in Section 3.5.3.1, where the upper threshold of the comfort zone and the upper threshold of the TNZ (UCT) are identified as the basis of a quantitative recommendation on microclimatic conditions during transport of different categories of pigs. CPs should be adequately designed and ventilated to maintain pigs in their TCZ. During cold weather conditions, CPs should provide indoor heating, and/or sufficient quantity of bedding and shelter so pigs can bury themselves into the bedding and maintain their body temperature at the required comfort levels.

Corrective/mitigating measure of heat stress

When animals show signs of heat stress, the effective temperature in the CP should be lowered. This can be achieved by increasing ventilation and/or by increasing space allowance. Animals can be cooled down using water sprinklers, showers, or equivalent.

iv) Prolonged hunger

See Sections 3.5.2iv and 3.5.3.3C for examination of the WC prolonged hunger during the transit stage. The main hazards for this WC in a CP are:

Time off feed: Pigs will typically have been off feed for at least 24 h when they arrive at a CP. Hence feeding motivation is (although yet un-quantified) most likely very high.

- PRE: The European handbook (Porcelluzzi, 2013) recommends that the minimum quantity of feed provided should correspond to the amount of food required for the body maintenance, and that feed must be of homogenous quality to avoid competition. In cases where *ad libitum* feeding is used, the report recommended one feeding place per 10 animals. If animals are not fed for *ad libitum* intake, one eating place per animal is recommended. To the best of our knowledge, these recommendations are not based on scientific data obtained in CPs. In addition, as mentioned above, if all feed-motivated pigs cannot eat simultaneously, it may lead to fighting and frustration. As the pigs will start a new transit stage after re-loading it is, however, important to make sure that they are not overfed at the time of re-loading, in order to prevent motion sickness. Research is needed to examine costs and benefits in terms of CP feeding management of pigs. See Section 3.3.2 for a discussion of time off-feed before the initiation of journeys.

Competition for access to feed: Feeding during journey breaks may cause competition between animals, and the stronger individuals may exclude the weaker ones.

- PRE: It is important that feeding space is enough for all animals to have access to feed simultaneously.

<u>Corrective/mitigating measures of prolonged hunger</u>

In the case that prolonged hunger is suspected in the CP, additional feed should be homogenously distributed among the animals. If re-loading is soon to take place, it will need to be delayed, allowing the pigs to eat first, and then digest before being reloaded.

v) Prolonged thirst

Prolonged thirst is regarded as a highly relevant WC in the CP stage even though pigs may arrive from journeys with access to water, because, so far, very limited documentation for proper intake of water, even in journeys in vehicles fitted with drinkers, is available. See Sections 3.5.2v and 3.5.3.3D for examination of the WC prolonged thirst during the transit stage. The hazards for this WC in a CP are:

Time off water: Irrespective of whether pigs have been drinking during the journey or not, the intake of feed at the CP will likely stimulate drinking motivation (however, not yet quantified).

- PRE: In the European handbook (Porcelluzzi, 2013), it is recommended for CP pens to be equipped with drinking devices and drinker height designed for the animal age group, and at least one drinker per 10 pigs is recommended. However, whether this recommendation is enough to avoid WCs is not known. The ratio of pigs to drinkers in CP is an area that should be studied, considering that animals may be thirsty when arriving, and all animals need to have the opportunity to drink and rehydrate during their stay at the CP.

Competition for access to water: Drinking during journey breaks may cause competition between animals, and the stronger individuals may exclude the weaker ones.

- PRE: It is important that drinking space is enough for all animals to have access to water simultaneously.

Corrective/mitigating measures of prolonged thirst

In the case that prolonged thirst is suspected in the CP, additional water should be homogenously distributed among the animals.

vi) Resting problems and restriction of movement

The physical conditions in a CP should allow for the pigs to be able to rest. Due to the novelty of the conditions, as well as mixing-induced group stress, pigs may experience thwarted resting motivation, and thus also be restricted in their movements. The main hazards for these WCs are:

Insufficient horizontal space (space allowance): The functionality of a CP depends on the ability of the animals staying there to rest. During a stay in a CP, it is crucial that pigs have time and possibility to eat, drink and rest. As mentioned above, pigs will most often be mixed at arrival, which means that some individuals likely will fight – sometimes during prolonged periods. The aggressive behaviours take up space.

- PRE: It is recommended that all animals in a CP pen should be able to rest at the same time. To the best of our knowledge, no studies have focused on resting behaviour of pigs in CPs. Both the European handbook (Porcelluzzi, 2013) and the Consortium on the Animal Transport Guidelines Project (2017), mention the risk of inadequate space allowance in CPs. In these guides, weaners of 20-30 kg are recommended an area of 0.26 m^2/pig, whereas gilts are recommended 0.63 m^2/pig, and sows/boars 1.22 m^2/pig. The reasons for these recommendations are not stated, and no evidence is provided to suggest that animal welfare is protected, as these numbers are lower than what is required on-farm. Whether the recommendations allow all pigs to rest when motivated to do so (because of individuals participating in fighting, exploring or seeking food and water, thereby disturbing their rest-seeking pen-mates) is not known. Research is needed to examine this, as well as to further develop CP-conditions to improve animal welfare, for example involving provision of functional areas for the pigs. A reasonable starting point would be to allow pigs at least the space required during housing conditions on farm (where they have time to wait for others to finish eating/drinking.

Corrective/mitigating measures of resting problems

In the case that resting problems or restriction of movements are suspected in the CP, a detailed inspection of the facilities should be performed, and potentially extra space and bedding should be provided.

Animals developing health conditions or becoming unfit: The flow of animals at a CP is a major issue with respect to the spread of diseases in and outside the EU (Transport Guidelines Project Consortium, 2017), with potential collateral consequences for animal welfare. Disease is always a challenge for animal welfare (as reviewed by Broom (2006)) and can lead to animals needing treatment or even turning unfit for transport during a journey. When journeys are prolonged, changes in the clinical condition of animals are a significant risk to their welfare. However, no scientifically published data to document changes in the clinical condition of pigs during and/or after journeys involving rest stops have been found. Hence, it is not possible to assess the size of this risk. This means that the use of mid-journey rest periods where pigs are unloaded to rest, feed and water have the potential to be counterproductive if inadequate attention is given to biosecurity. There are numerous infectious diseases to which pigs are susceptible that require biosecurity practices to prevent transmission. When pigs are unloaded during a journey, there is an increased risk of contact with infected animals or facilities, e.g. inadequately cleaned and disinfected areas. Pathogens can be transmitted to susceptible pigs by direct contact with infected animals, by mechanical transfer on people, non-susceptible animals, birds, vehicles and fomites, and by aerosols (Neumann and Hall, 2019). Among relevant examples are faecal pathogens (*Salmonella enterica* biovars and *Escherichia coli*) transmitted through shedding (Isaacson et al., 1999). Many other pathogens including porcine epidemic diarrhoea, porcine reproductive and respiratory syndrome, foot and mouth disease or African swine fever can be potentially spread while unloading animals, if adequate biosecurity measures are not put in place (Lowe et al., 2014; Filippitzi et al., 2018 and Beltran-Alcrudo et al., 2019). To the best of our knowledge, whether the physical conditions at CPs allow proper veterinary inspection (checking individual animals can be difficult when pigs are kept in large groups) or not, is not known.

To date, only one study has been identified reporting data on mortality or morbidity (including animals declared unfit for transport by official veterinarians at the CP). Padalino et al. (2018) reported the official recordings of mortality and morbidity in an Italian CP during 2010–2015, a period where 111,536 animals of different species passed through. Of these, 4.8% (corresponding to 5,333) were pigs, the majority of which were either light (110–120) or heavy (150–160 kg) finishers and the rest were > 200 kg animals. According to the data reported by Padalino et al. (2018), no pigs were recorded as 'unfit for transport', no pigs were reported dead, and no morbidity was recorded either. Whether these findings are a true picture, reflect lack of proper inspection, or can be explained by the relatively low sample size is not known.

- PRE: Staff should be trained on the inspection of animals at the CP to detect signs of weakness or illness on fatigued or injured animals that may compromise their fitness for further transport (see Section 3.3.3). Animals showing signs of weakness or disease should be inspected and treated accordingly, as described below.
- PRE: The risk of spread of diseases can be limited by managing an all-in all-out principle at CPs as well as by thorough cleaning and disinfection between batches.

Corrective/mitigating measures for animals developing health conditions

Animals showing signs of weakness or disease should be treated appropriately, preferably in a hospital pen or similar. These animals may require specific handling and treatment, so contingency plans should be in place for injured and sick animals. Animals that are unfit for further transport should not follow the consignment at re-loading, but be slaughtered, treated or euthanised according to the prognosis of their condition.

3.6.4. Journey break – summarising considerations

At some stage during a journey, pigs will need feed, water and rest in order to avoid being exposed to hazards leading to WCs such as prolonged hunger, prolonged thirst and resting problems.

Regarding provision of feed, the tendency for pigs to develop motion sickness, means that provision of feed to pigs on stationary vehicles during breaks in driving, likely will be difficult, as the journey probably cannot be continued until hours after the feeding of the animals. Research is needed to clarify costs and benefits of such practice.

Theoretically, unloading pigs into a pen allows the animals to have access to resting, watering and feeding areas in order to mitigate the WCs of transport. However, stopping a journey to unload the animals to provide a period of rest, feed, and water involves a number of hazards relevant for animal welfare such as the risk of stress, injury and infectious diseases. Some of these can be mitigated by the duration of the stay, some by offering high quality conditions to the animals, whereas others, such as the novelty of the surroundings, the extra unloading and reloading, and the mixing of unfamiliar animals as well as the inherent biosecurity risk, cannot be avoided. Thus, whether there are always beneficial effects for the welfare of pigs for a long journey to be interrupted to offer feed and water while unloaded is equivocal, as currently, no data documenting the benefits of a stay in a CP (including physical layout and/or the animal management) in terms of pig welfare are available, and no data are available to assess the appropriate duration of a stay in a CP for pigs.

3.7. Specific scenarios: Transport of cull sows to slaughter

A) Current practice

Even though the main product of the pig industry is meat from finisher pigs (~ 100–130 kg depending on MS), also sows (and boars) are slaughtered after their productive lives. The term 'cull sow' describes sows, for whom stockpersons/herd owners have decided to end the productive phase. The majority of cull sows are sent to slaughter, but some may be killed on-farm. This section focuses on sows sent to slaughter, a group of animals that constitute a distinct animal category within pig production. The timing of a decision to cull a sow depends on several factors, and cull sows are, thus, a rather diverse group constituting sows as young as parity 1 and above parity 10. Among the available studies of cull sows, a median parity of ~ 5 seems typical (De Jong et al., 2014; Zhao et al., 2015; Fogsgaard et al., 2018).

Across European countries, it is not unusual to cull approximately half of the sows in a herd per year. This means that millions of European sows are culled and sent to slaughter each year. The transport of sows to slaughter takes place entirely by road, either within or between MS. Among the MS, a few (Sweden and Denmark) have national regulation setting a limit of 8 h of journey duration for sows.

Farmers typically send a relatively low proportion of their sow population to slaughter at the same time, which means that vehicles typically will visit several herds to make a full load on their way to a slaughterhouse, or collect animals from an assembly centre. In addition, only relatively few slaughterhouses accept sows. Taken together, this means that sows often will be transported either quite far, or for quite some time, to reach the slaughterhouse. The need for several stops on the way, to load sows from other herds, can be a challenge for the biosecurity of the visited herds. One way to limit the risk of spread of diseases from vehicles transporting sows visiting several herds, can be the use of so called 'pick-up vehicles' (or 'transfer vehicles', see Figure 1 of this Scientific Opinion). Instead of allowing vehicles already holding other sows on board to back-up close to their buildings, some farmers load the sows to be culled on a particular day into some vehicle and transports this vehicle to the nearest public road. When the truck arrives to pick up the sows, it does not come near the farm buildings, but the sows are loaded from the 'pick-up vehicle' and onto the truck. Depending on the duration of the stay in the pick-up vehicle, the interval between leaving the home pen and arriving at the slaughterhouse may be considerably longer than the journey itself, and these vehicles can be said to constitute one extra link in the pre-slaughter logistic chain (Miranda-De La Lama et al., 2014; Herskin et al., 2017).

Another category of cull pigs is boars. Boars are used in pig production facilities as 'teaser' boars for facilitating detection and stimulation of sows in heat, and in large numbers in genetic boar studs for the production of semen for artificial insemination (Hook et al., 2010) where the turnover of boars is high and annual replacement rates range from 50% to 145% (Robinson and Buhr, 2005). Boars therefore form a smaller, yet consistent sub-population of adult pigs being transported. Boars being transported from breeding nucleus herds to commercial farms for use as teaser boars are likely to be young and healthy, whereas cull boars at the end of their productive life may show signs of impaired health. Health impairment accounted for 13–60% of annual culling from seven boar studs in Europe and North America (Robinson and Buhr, 2005), and feet and leg problems were reported to be the 3rd most common reason for culling boars identified in a survey of North American boar studs (Knox et al., 2008). Additionally, due to the typically isolated location of genetic nucleus herds, and the general trend towards consolidation of facilities that will slaughter and process boars, boars may undergo longer transport durations than other pig categories. Despite the potential welfare concerns during boar transport, no studies have been found to inform conclusions or recommendations.

B) Concerns specific to cull sows being transported by road

From an animal welfare point of view, transport of cull sows involves a number of concerns, the characteristics of which have been brought up by scientific publications (Nielsen et al., 2011; Grandin, 2016a,b), for example based on increased mortality upon arrival at the slaughterhouse compared with finishers (Lykke et al., 2007; Malena et al., 2007; Peterson et al., 2017). Recently, scientific attention has been directed towards this category of pigs, but knowledge about cull sows is still massively lacking behind the other pig categories such as finishers or lactating sows on farm. Among the primary concerns for the welfare of cull sows during transport are (i) fitness for transport (Grandin, 2016a,b); (ii) the high sensitivity towards heat stress that characterises modern pig breeds (Brown-Brandl et al., 2014; Cabezon et al., 2017); and (iii) the tendency to fight when unfamiliar sows are mixed. Below, these three concerns are described further.

i) Fitness for transport

Herskin et al. (2017) analised the behaviour of cull sows while waiting for transport, reviewing as well the main reasons for culling them: 'As discussed by De Jong et al. (2014), reasons for culling of sows are influenced by factors such as sow genotype, housing conditions and management policies. Studies focusing on reports from farmers, such as Zhao et al. (2015), found that almost 80% of sows sent to slaughter were not culled as part of a strategy, and that the vast majority of sows were culled due to reproductive problems or reduced health. Similar conclusions have been drawn from studies involving clinical examination of sows upon arrival at slaughterhouses in Europe (De Jong et al., 2014) and the US (De Hollander et al., 2015). By studying the interval from insemination to culling, De Hollander et al. (2015) showed that a large proportion of sows were culled after weaning, and similar findings were reported by Engblom et al. (2007)'.

The concerns for the fitness for transport of cull sows are thus based on the following: (1) health impairment and/or reproductive problems (including lack of pregnancy) are among the main reasons to cull sows; (2) sows slaughtered at the end of their reproductive life are typically not young at the time of slaughter (although some young sows failing to get pregnant will be included); and (3) studies showing increased mortality upon arrival at the slaughterhouse in sows (Malena et al., 2007; Lykke et al., 2007a,b; Peterson et al., 2017).

Only a few studies have characterised cull sows clinically before departure from herds. In one of these, Fogsgaard et al. (2018) presented data from 47 loads of sows, originating from 12 Danish herds, and sent to slaughter over a 1-year period. From this study, involving only sows that the farmers had already selected for slaughter, more than 50% of the sows had at least one wound (defined as at least 1 cm) on the body, almost 1/3 had superficial skin lesions, 11% were observed with decubital shoulder ulcers, 25% had at least one udder lesion, 12% were observed with vulva discharge and 10% showed signs of abnormal gait. In addition, 39% of the sows were lactating at the time of the clinical examination (the morning before departure).

Even though no data exist to document the proportion of lactating animals among cull sows, recent studies suggest that it is not unusual to send sows to slaughter on the day of (or the day after) weaning. In comparison with dairy cows where milk leakage and reduced lying time have been reported after abrupt cessation of milking (e.g. Leitner et al., 2007; Zobel et al., 2013), limited scientific attention has been focused on the discomfort of sows due to abrupt cessation of lactation at weaning. Modern lactating sows are, due to the large litter sizes and high genetic potential for milk production, sensitive towards heat stress, especially close to weaning, where milk production is peaking (Williams et al., 2013). Hence, sending sows to slaughter may involve thermal challenges, especially for lactating sows, and hyperthermia has been suggested to be among the main reasons for cull sow mortality upon arrival to slaughterhouses (Peterson et al., 2017).

As reviewed by Fogsgaard et al. (2018) 'decubital shoulder ulcers have been associated with behavioral changes (Larsen et al., 2015) and are suggested to be painful (Herskin et al., 2011; Dahl-Pedersen et al., 2013). The consequences of pretransportation conditions/activities and actual transportation for sows with decubital shoulder ulcers are not studied. Mixing, fighting, and standing in the moving truck are likely to result in worsening of the ulcers, as the ulcers might be torn open or to be perceived more painful due to mechanical pressure/'bumping into inventory'. When cull sows were examined before and after transport, shoulder ulcer characteristics were reported to change. Thodberg et al. (2019) observed increased post-transport occurrence of reddening in and around the ulcers. This means that the presence of ulcers and perhaps even scars may have adverse consequences for sows during transport.

The concern for the fitness for transport of cull sows was deepened by the data from Thodberg et al. (2019), involving clinical characterisation of the same sows as involved in the study by Fogsgaard et al. (2018), upon arrival to the slaughterhouse after a road journey in approved vehicles for up to 8 h (46–469 min; mean: 232 min) under conditions conforming to Council Regulation (EC) No 1/2005[1]) regarding space, ventilation, etc. When comparing the clinical condition of the sows before and after the journey, a deterioration was found for a considerable proportion of the clinical measures, such as an increased number of superficial skin lesions, increased number of wounds, increased occurrence of swollen and red areas, increased number of torn off hoofs and increased number of vulva lesions.

If the findings of the two Danish studies are representative for European conditions, they raise concern regarding the vulnerability of this particular category of pigs when exposed to stressors common during transport such as mixing or lack of adequate possibility to thermoregulate. Thus, depending on how animal fitness for transport is defined, (e.g. if fitness means that animals should arrive at their destination in a similar condition to that assessed before loading with minimal deterioration during their journey), it can thus be discussed whether cull sows are fit for the presently used transport conditions at all. There has, however, not been extensive research on how sows with different health issues respond to transport.

Recommendations from the World Organisation for Animal Health (WOAH) (2011) underline the possible vulnerability of cull sows and state that, for example, old, lactating and aggressive animals require special conditions on the day of slaughter in order to ensure their welfare.

ii) Group stress

Under natural or semi-natural conditions, adult female pigs live in relatively small groups consisting of genetically related individuals. Within a group, the animals have a well-established hierarchy, and overt fighting between group members is not often seen. In international pig production, pregnant sows are increasingly kept in groups, but often managed in a way where mixing of unfamiliar individuals happens several times during each production cycle. This management practice has received considerable scientific attention, and it is well-documented that sows – when mixed with unfamiliar individuals – will fight to re-establish a hierarchy, and that the fighting can be severe and of considerable duration (Mount and Seabrook, 1993; Arey and Edwards, 1998). Consequently, the mixing of unfamiliar sows has long been recognised as a welfare problem, mainly due to inter-sow aggression (Greenwood et al., 2014).

Herskin et al. (2020) and Thodberg et al. (2020) conducted surveys among sow herd owners and livestock drivers, respectively. One central outcome of these was the clear answer 'yes', when asked about whether sows are mixed before and/or during transport to slaughter. Consequently, it is highly likely that sows are also fighting when mixed in this phase of their life. No studies have documented sow behaviour onboard transport vehicles, but Thodberg et al. (2019) found increased occurrence of superficial skin lesions in sows after arrival to the slaughterhouse, possibly the outcome of intra-journey fighting. Herskin et al. (2020) studied the behaviour of cull sows during 6 h after mixing in on-farm pick-up pens before transport and observed a median occurrence of aggressive interactions per pen holding 3-4 sows of 33, ranging from 11 to 55. In addition, based on a small data set on the behaviour of sows when kept in pick-up vehicles before being picked up by larger trucks, Herskin et al. (2017) recorded incidents of aggression even when the stay was shorter than 10 min. Hence, even though documentation as such is missing, it is highly likely that sows will fight during transport, when mixed with unfamiliar individuals, and this behaviour constitutes a hazard for the continuous fitness for transport, the risk of heat stress, of group stress as well as the overall welfare of the sows.

iii) Heat stress

As mentioned in Section 3.5.3.1F, the upper threshold of the TCZ of lactating sows may be lower than 20°C, and the UCT is suggested to be ~ 22°C for these animals. Lactating sows are especially sensitive to heat stress in the days before weaning of the piglets, when milk production is peaking (Williams et al., 2013). Examination of heat production of sows has shown a steady increase from farrowing until weaning (Brown-Brandl et al., 2014). However, as reviewed by Bracke et al. (2020), almost all available data on heat stress in sows comes from on-farm studies, and deals with lactating sows kept in typical housing systems such as farrowing crates.

Temperature data collected from inside the compartments of approved trucks (unknown number of trucks), transporting 39 loads of cull sows to slaughter in Denmark in spring, summer, autumn and winter in journeys lasting up to 8 h, identified that, when sows were kept at a maximum of the recommended Danish stocking density of 0.80 m^2/250 kg sow, and with passive ventilation and the possibility for the driver to activate mechanical ventilation, truck temperatures (measured by sensors placed near the ceiling of the rear compartment on the lower deck) did not stay within the TCZ of sows, and even rose above the UCT in summer during non-stationary periods, and in summer and autumn during waiting at unloading (Thodberg et al., 2022). Importantly, during the journeys, the drivers of the vehicles were not notified about these data, and thus, may not have adjusted the use of mechanical ventilation accordingly. This suggests that improved ventilation methods and/or warning systems based on temperatures measured close to the bodies of the pigs, are required, maybe in combination with changes in stocking density (at least in the warmest compartments in the front top of the truck), as these journeys took place during a regular summer with not many extremes of temperature.

As mentioned, in order to obtain a full load, sow trucks may stop at several farms to collect sows and most trucks experience some waiting time at the slaughterhouse for unloading or stationary periods due to traffic or driver breaks (according to Thodberg et al. (2022) reported to range from 5 to 159 min), situations in which temperatures rise quickly to levels where sows would experience heat stress, with the internal truck temperature increasing by 7°C during a 10 min stationary period (Thodberg et al., 2022).

The frequency of sow aggressive interactions has been found to correlate with temperature inside the pick-up vehicle (Herskin et al., 2017), which may be a product of sows becoming more restless and also possibly trying to move away from one another in warmer temperatures, but being hindered by limited space.

3.8. Specific scenarios: 'Special health status pigs'

A) Current practice

In some cases, pigs are transported from a herd (or region/country) with a higher health status than the general animal population, through an area with a lower health status, to a new herd (or region/country) with a higher health status. In such cases, the herd (or region/country) receiving the pigs does not want them exposed to the general pig population during the course of any given journey. Therefore, journeys taking place without unloading the pigs during the journey may be advantageous. The focus here is on the transport of pigs on journeys by road without unloading them before their final destination.

Due to biosecurity concerns, pigs (typically weaners or breeding animals) are not unloaded to provide required rest, feed and water, when the maximum journey time is reached.

B) Concerns specific to pigs when they would not be unloaded from the vehicle

The WCs selected as highly relevant for pigs during the transit stage (group stress, heat stress, injuries, motion stress and sensory overstimulation, prolonged hunger, prolonged thirst, resting problems and restriction of movement) have already been dealt with in Section 3.5.2. Recommendations have been made in Section 3.5.2 that attempt to prevent the hazards and mitigate the WCs. However, pigs not unloaded before their final destination presents a larger risk with respect to their welfare. In such cases, facilities must be available on the vehicle to provide the necessary resting, feeding and drinking, and a suitable microclimatic environment. No scientific studies have been found that can demonstrate effective feeding and watering of pigs during transport. Knowledge about the quality of resting on a vehicle (moving or stationary) is also lacking. Air and bedding quality are other important issues that have not been studied in such a context.

The maximum duration of journeys without unloading the pigs has not been studied. The impact of rest periods has not been studied either, nor has the impact of repeated driving and resting. This constitutes gaps in knowledge.

3.9. Specific scenario: The transport of pigs by air

A) Current practice

The transport of livestock by air happens at low level when compared to road transport but it can still be part of industry practice, involving especially breeding animals. According to TRACES, in 2019, 2020 and 2021, 8,582, 29,661 and 65,664 pigs were transported by air, between MS or exported to third countries.

The transport of pigs by air starts with a journey by road from a farm or assembly centre to an airport where the pigs are unloaded from the road transport vehicles and loaded into transport crates. These crates are then loaded into an aircraft. Upon arrival at the airport of destination, the crates are unloaded from the plane and brought to an area where the pigs are removed from the crates and loaded into road transport vehicles to continue their journey.

B) Concerns specific to pigs transported by air

The WCs, hazards, preventive and corrective measures explained before in the transport by road (Sections 3.3, 3.4 and 3.5) also apply here. In addition, the transport by air presents certain concerns that are addressed below. No studies have been found focusing on the welfare of pigs during air transport. Hence, this assessment is based on expert opinion and general knowledge about air transport and animal transport.

Among the welfare concerns identified for air transport of pigs are high density confinement in crates, lengthy waiting times, extended periods of water and feed deprivation, variation in microclimatic conditions, and mixing of unfamiliar individuals. Other factors that may cause animal discomfort are motion stress and loud noises.

3.10. Specific scenario: The transport of pigs by train

A) Current practice

Rail is the means of transport used the least for pigs. According to TRACES, in 2020 and 2021, ~ 500 pigs were transported by rail between MS. The transport of pigs by rail starts with a journey by road from a farm or assembly centre to a train station where the pigs are unloaded from the road transport vehicles and loaded unto the train. Upon arrival at the train station of destination, the pigs are unloaded from the train and loaded into road transport vehicles to continue their journey.

B) Concerns specific to pigs transported by rail

No scientific literature pertaining to the transport of pigs by rail were found. However, based on expert opinion and general knowledge about rail transport and animal transport, the following welfare concerns were identified.

The WCs and hazards identified in Sections 3.3, 3.4 and 3.5 are all applicable to the transport of pigs by rail. The unloading of pigs from a vehicle at a railway station with the subsequent loading onto a railway carriage is a procedure requiring care. Similarly, the unloading of a railway carriage and the loading of a vehicle requires equal care. The animal handling facilities present in a railway station are of particular importance. This includes races/chutes and pens that will allow the pigs to be safely moved from the ramp of a vehicle to the loading ramp of the railway carriage. Among other welfare concerns identified for rail transport of pigs are high density confinement in railway carriages, lengthy waiting times, extended periods of water and feed deprivation, variation in microclimatic conditions, and mixing of unfamiliar conspecifics.

3.11. Uncertainty analysis

The uncertainty in the assessment performed for this Scientific Opinion was investigated in a qualitative manner following the procedure detailed in the EFSA guidance on uncertainty analysis in scientific assessments (EFSA Scientific Committee, 2018). The outcome of this Scientific Opinion is the identification and description of the highly relevant WCs, the related ABMs - measured in a qualitative or quantitative way - and hazards causing these WCs. Based on this identification and listing of WCs and ABMs, conclusions and recommendations are formulated allowing for different mitigation and preventing measures for the identified WCs (resource and management-based measures). As the identification and listing of the highly relevant WCs and ABMs was mainly based on expert opinion (integrating the severity, duration and prevalence of each WC) and not on a full comprehensive risk assessment, the uncertainty analysis was limited to the identification and description of the sources of uncertainty in the assessment carried out. A table describing the sources of uncertainty associated with the methodology used in the assessment is presented below (Table 27).

Table 27: Sources of uncertainty (in a non-prioritised order) associated with the assessment methodology and inputs (extensive literature search, expert's opinions) for the identification and assessment of the most relevant WCs and ABMs

Source of Uncertainty	Nature or cause of the uncertainty	Impact of the uncertainty on the assessment
Literature search – Language	The search was performed exclusively in English. More studies could have been identified by including references in languages other than English.	WCs might have been selected that in reality belonged to another category than highly relevant, and WCs that in reality were highly relevant might have missed to be selected.
Literature search – Publication type	The studies considered included primary research studies identified through the extensive literature search and grey literature (fact sheets, guidelines, conference papers, EU reports, book chapters, etc.) known to the EFSA Experts, but an extensive search of the grey literature was not conducted. Therefore, there may be reports and other guidance documents on animal welfare of which the EFSA Experts were not aware off.	Underestimation of the published relevant studies.
Literature search – Search strings	Although the search criteria were thoroughly discussed, some synonyms may have not been used in the search strings, and thus less hits might have been retrieved. In addition, literature from non-transport conditions, that may still have been relevant for the assessment, may also not have been found.	The understanding of the relation between hazards and ABMs may not be complete due to having missed data.
Literature search – data sources	The search was limited to Web of Science. Although the search was complemented by internet searches and manual searches of the publicly available literature, no data were retrieved from other sources (e.g. industry, NGO or authority data). More information could have been retrieved by applying a different methodology (e.g. public call for data).	The understanding of the relation between hazards and ABMs may not be complete due to having missed data.
Literature search – inclusion and exclusion criteria	The screening phase might have led to the exclusion of certain studies that could have included relevant information.	Underestimation of the published relevant papers.
Expert group – number of experts, type of experts	This SO was carried out by a working group of 12 EFSA Experts, of whom 3–5 were species-specific experts. The approaches underlying the SO is based on expertise from the whole working group, whereas the vast majority of the text within the SO has been written by the species-specific experts. Experts had to show they have no conflict of interest due to, e.g. involvement with the pig industry or NGOs. This may have resulted in reduced level of technical and applied expertise.	As the highly relevant welfare consequences were selected by expert opinion, the experts might have selected WCs that in reality belonged to another category than the highly relevant ones, and might have missed to select WCs that were in reality highly relevant.
Transport conditions of the studies retrieved in the extensive literature search	The transport conditions of the studies retrieved might have differed from the ones currently used in the EU, thus requiring an extrapolation exercise from the experts.	Under- or overestimation of the level of magnitude of the welfare consequences and related ABMs.

Source of Uncertainty	Nature or cause of the uncertainty	Impact of the uncertainty on the assessment
Husbandry practices and pig breeds and categories of the studies retrieved in the extensive literature search	The studies retrieved may have involved husbandry practices and pig breeds and categories differing from EU-standards. Thus, experts had to extrapolate findings to the EU relevant conditions in some cases.	Under- or overestimation of the level of magnitude of the welfare consequences and related ABMs.
Transport conditions of the studies retrieved in the extensive literature search	Transport conditions (e.g. driving style, ventilation capacity of the vehicle, external temperature) were not always specified in all the studies retrieved.	Under or overestimation of the effects of the transport conditions on the WCs selected.
Time allocation	The time and resources allocated to this SO were limited and additional time for reflection would have facilitated a more in-depth discussion of some of the aspects.	Inclusion, under- or overestimation of the level of magnitude of the WCs and related ABMs.
Lack of ABMs that are documented to be useful during transport in terms of feasibility, sensitivity or specificity	Based on the available knowledge, it was not possible to use single ABMs to assess the effect of exposure variables and transport conditions on welfare consequences.	Under- or overestimation of the level of magnitude of the WCs.
Transport being a complex stressor, for which animal welfare has been studied much less than animal housing	The complexity of animal transport with the many interacting hazards and thus WCs, means that many WCs are relevant, and thus that some can be missed in the selection of the highly relevant.	WCs that are in reality highly relevant are missed and thus underestimated.
Lack of available studies done under the recommended conditions	The number of studies available involving the conditions recommended in this SO is very limited. In addition, there are very few recent European studies. Thus, in some cases, and especially for the assessment of the journey time, experts had to extrapolate findings from studies done under different conditions.	Under- or overestimation of the level of magnitude of the welfare consequences.

4. Conclusions

The following section lists the conclusions of this Scientific Opinion

4.1. General conclusions on transport of pigs

- There are published protocols to assess animal welfare on farm and at slaughter, but no validated protocols are available to assess the welfare of pigs during transport.
- ABMs based on expert opinion for all highly relevant WCs along the transport stages are available (see Section 3.2.2). None of these, however, have been documented to be useful during transport in terms of feasibility, sensitivity or specificity.
- The use of ABMs in animal transport is hampered by the reduced access to animals particularly during the transit stage, but their use may be more feasible during other transport stages (e.g. loading/unloading).
- Technological development, such as intelligence-based camera systems or motion sensors, may increase the possibility to record and/or monitor ABMs during the entire transport process. However, such systems are not yet available in practice.
- Many hazards during the transport of pigs have been identified (see examples below for each transport stage). The consequences of the exposure to them often goes across journey stages (see Sections 3.3, 3.4, 3.5 and 3.6).

- Some hazards affecting the condition in which the animal begins the journey (e.g. level of hunger or thirst or health status) can only be mitigated or prevented before transport, although their associated WCs may appear later.
- Several sources of uncertainty were identified during the assessment, including (a) transport being a complex stressor, the consequences of which in terms of animal welfare have been studied much less than, e.g. for animal housing, especially under European conditions; (b) lack of ABMs that are documented to be useful during transport in terms of feasibility, sensitivity or specificity; (c) lack of available studies done under the recommended conditions; (d) lack of time; and (e) low number of experts involved. However, the impact of uncertainty was not quantified. A list of the major sources of uncertainty can be found in Table 27.

4.2. Conclusions on the preparation of pigs before transport

- The preparation phase is important for the protection of the welfare of pigs throughout the journey, lack of good preparation may lead to WCs.
- At present, no published protocols to assess animal welfare during preparation for transport are available.
- If transport of animals involves complex journeys including markets, assembly centres or other temporary stops, there will in principle be preparation at several levels – before the initiation of the journey and before each re-loading of the animals.
- So far, the scientific focus addressing the preparation phase has been limited, especially concerning the transport of cull sows and boars as well as pigs transported for further fattening.
- Group stress, handling stress, heat stress, injuries and resting problems are the highly relevant WCs during the preparation of pigs for transport.
- Pigs, especially finishers, are often fasted before transport. This is done for several reasons not directly related to animal welfare (e.g. food safety and hygiene) that are not covered in the Scientific Opinion. From an animal welfare point of view, fasting leads to WCs, such as prolonged hunger and may indirectly lead to group stress, injuries and handling stress. Lack of fasting may also have consequences for the animals in terms of increased risk of motion sickness and hyperthermia. The underlying evidence to support fasting from an animal welfare point of view is not strong, and only involves finishers transported to slaughter. This constitutes a gap in knowledge.
- The longer the pre-transport fast, the sooner the WC prolonged hunger will appear during the following transport stages.

A) Fitness for transport

- The assessment of fitness for transport (Section 3.3.3) before departure is of utmost importance in the protection of pig welfare. However, currently no scientific definition of the concept of fitness for transport exists.
- If pigs are not properly assessed, and unfit animals are loaded, it is a hazard for their welfare, predisposing them to different WCs during later transport stages, and potentially leading to negative affective states such as discomfort, pain and suffering.
- Characteristics rendering animals unfit for transport are mainly related to health impairment, but not always, as for example certain age groups or certain physiological stages lead to animals being unfit for transport. Even though some guidance for assessing fitness for transport is available, however due to difference in implementation this leads to unreliability. Variation between assessments is documented. A list of conditions that make animals unfit to be transported has been provided in this Opinion. Some of these still require scientific validation and further study to identify the severity of the potential WCs that can arise when they are present.
- At present, thresholds for ABMs as indicators of animals being unfit for transport have seldom been established or validated. More knowledge about these is needed.
- Additional knowledge about pre-existing conditions that potentially lead to negative affective states during transport (e.g. lameness), is also needed. If these conditions are not mentioned in this Opinion, they will need to be added and ABMs need to be established to assess them.

- Successful assessment of fitness for transport requires well-educated staff (including professional groups such as veterinarians, farmers, herdsmen and livestock drivers), full clarity on responsibility, and a clear definition of the concept of fitness for transport.
- Advanced pregnancy is associated with increased risks of WCs during transport. There is European legislation as well as consensus across different available guidelines that pigs should not be transported in the last 10% of their pregnancy. However, scientific evidence to support this threshold is lacking, and the risk of reduced animal welfare may be present earlier.
- In cases where animals are considered fit for transport, but their fitness may be reduced, potential measures mitigating WCs are (a) shortened journey duration, (b) increased amount of bedding, (c) loading the affected animal last and unloading the animal first, and (d) providing sufficient space to lie down. However, the effectiveness of such mitigation measures to avoid the additional suffering has not been proven. This constitutes a gap in knowledge.

4.3. Conclusions for loading/unloading of pigs during road transport

- The highly relevant WCs during loading/unloading of pigs are: handling stress, heat stress, and sensory overstimulation.
- Across the highly relevant WCs, the major hazards are inappropriate handling, unsuitable facilities and high temperatures. A delay in loading and/or unloading is a hazard for a deterioration of these WCs.
- The main preventive measures are establishment and maintenance of proper facilities, avoiding loading during hot hours and education and training of handlers.

4.4. Conclusions for the transit stage during road transport of pigs

- The highly relevant WCs for pigs during the transit stage are group stress, heat stress, injuries, motion stress and sensory overstimulation, prolonged hunger, prolonged thirst, resting problems and restriction of movement.
- Among the major hazards for animal welfare during the transit stage are high effective temperatures, mixing of unfamiliar animals, insufficient space allowance, time off feed and water, reduced intake of water, vehicle movements and lack of possibility to rest.
- Preventive and corrective/mitigating measures have been suggested (see Section 3.5.2). Several of the highly relevant WCs of the transit stage (e.g. motion stress, resting problems, restriction of movement) cannot be fully prevented.
- So far, no scientific evidence quantifying water intake as adequately is available, even in journeys with vehicles fitted with drinkers.
- The severity of the WCs during the transit stage of transport will depend on the exact conditions pertaining to an individual journey (e.g. microclimatic conditions, space allowance and road conditions). The hazards relating to these conditions potentially interact. The exposure to these hazards will continue at least as long as the journey continues.

A) Microclimatic conditions

- Pigs are special among mammals in that they have difficulty in dissipating heat. Thus, pigs are more vulnerable to heat stress, especially at ambient temperatures with high humidity, than most other farm animals.
- There is growing evidence that genetic selection for productivity has reduced the pigs' ability to cope with heat stress. It has not been possible to find data to clarify whether pigs of certain breeds, or from certain regions of the EU are better adapted to sustain heat stress than others. This warrants further study.
- Larger pigs, especially lactating sows, are more vulnerable to heat stress than smaller pigs. Compared to the other categories of pigs typically subjected to transport, weaners are likely to be the least vulnerable to heat stress. The available information for boars is very limited.
- If temperature in the transport vehicle remains below the upper limit of the TCZ, pigs will most likely not experience stress or negative affective states associated with heat stress during transport.
- The WC heat stress may start when pigs are no longer in their thermal comfort zone, and the risk and severity of heat stress is high when the thermal conditions reach the UCT.

- Not only the temperature in the vehicle, but also other environmental conditions influence heat load placed on pigs during transport, such as humidity, thermal radiation, temperature of surrounding surfaces and wind speed. These will all influence the microclimatic conditions experienced by pigs and should, in theory, all be taken into account when microclimatic conditions of pigs during transport are evaluated. In addition to dry temperature, humidity is considered the most important of these to take into consideration.
- The available information on thermoregulation of the three relevant categories of pigs has allowed for estimates of thresholds for TCZ and for UCT (Table 28) although uncertainty exists regarding these values.

Table 28: Estimates of upper thermal thresholds for the thermal comfort zone and the upper critical temperature (°C) for pigs

	Upper threshold of thermal comfort zone	Upper critical temperature
Weaners of ~ 30 kg	25°C	30°C
Finishing pigs	22°C	25°C
Sows	20°C	22°C

- Although sensors only recording temperature have been used in transport of livestock so far, it would be a significant refinement to use sensors taking account of other environmental conditions influencing heat load placed on pigs during transport (preferably a combination of temperature and humidity). For variations of dry temperature and relative humidity, the higher the levels of relative humidity, the lower the upper thresholds of TCZ and UCT will be, when measured as a dry temperature only.

B) Space requirements

- The allometric equation [$A = k \times W^{2/3}$] (where A is Area in m^2 per animal, and W is liveweight in kg) can be used to calculate the physical space requirements of any category of pigs.
- For this Scientific Opinion, the minimum space allowance is set by the first limiting factor reducing the ability of pigs to undertake relevant biological functions during transport. One such function is the ability to adjust posture in response to acceleration and other events related to driving. However, no studies have been found to provide evidence regarding this biological function. This is a gap in knowledge.
- Regarding space for thermoregulation and provision of water during transport, there is insufficient evidence to provide a quantification of the minimal space required to fulfil these biological functions under transport conditions.
- Based on the available evidence for the remaining biological functions, the available evidence suggests that a k-value of at least 0.027 is required. Providing pigs this space during transport will allow all animals in a compartment to lie down in a semi-recumbent posture. Whether provision of this space during transport can allow pigs space to adjust posture in response to acceleration and other events related to driving, space for thermoregulation and for effective provision of water during transport is not known.
- Table 29 gives estimates of the minimum space allowance suggested for pigs during transport.

Table 29: Minimum space allowance (based on allometric equation) suggested for pigs of different body weights

Approximate weight	Area (m^2/animal)
30 kg	0.26
110 kg	0.62
160 kg	0.79
240 kg	1.04

- The vertical space in a means of transport is important for animal welfare. Low vertical space is associated with reduced ventilation, lack of ability to move around and lack of space for natural movements, and should be prevented in order to avoid WCs such as heat stress and restriction of movement. No studies have established a proper deck height for pigs during transport. There are equations to estimate the height of pigs, but a lack of data to determine the appropriate deck height for different pig categories in order to protect their welfare during transport. Research is needed to establish evidence-based thresholds.

C) Journey times

The conclusions regarding journey time are based on a scenario where animals are transported under the microclimatic conditions and with the minimal space allowance recommended in Sections 3.5.3.1 and 3.5.3.2, respectively. The implications of these are that the risk and severity of the WCs heat stress and restriction of movement are much reduced and are thus given less weighting in the conclusions and recommendations on journey duration.

The remaining highly relevant WCs can be classified into those that are **continuous or semi-continuous** (i.e. begin with the onset of the journey and occur continuously or intermittently throughout its duration), those that are **progressive** (i.e. may not be present at the beginning of the journey but develop progressively as it continues), and those that are **sporadic** (i.e. problems in individual animals which may be exacerbation of a pre-existing condition or may occur spontaneously at any point in the journey and whose WCs will continue thereafter). These are summarised in Table 30.

Table 30: Summary of conclusions on the development of welfare consequences over journey time

Type of welfare consequence	Welfare consequence	Development over time	Expected development over time
Continuous or semi-continuous	Motion stress	Continuing throughout the transit stage	Severity will increase over time leading to fatigue
	Sensory overstimulation	Sensory overstimulation repeated intermittent	Can lead to fear and distress
	Group stress and resultant injuries (skin lesions)	Continuing throughout the transit stage, but development over time not known	Group stress may lead to fatigue, injuries will lead to pain and/or discomfort.
	Resting problems	Continuous throughout the transit stage	Severity will increase over time leading to fatigue
Progressively developing	Prolonged thirst	Available information shows that behavioural and physiological signs of thirst can be present after 8 h of transport without effectively accessing water.	Severity will increase with time, leading to dehydration and potentially suffering
	Prolonged hunger	Available information shows that behavioural and physiological signs of hunger can be present after 12 h of feed deprivation. Depending on the pre-transport fasting this may correspond with the early hours of the journey.	Severity will increase with time, leading to weakening and exhaustion
Sporadic	Pain and/or discomfort from health conditions	May start at any time if pre-existing health conditions are present or occur during transport	If present, severity will increase with time, leading to suffering

Below, the prevalence, the severity and the duration of each of the highly relevant WCs involved in this assessment are summarised:

- Motion stress and sensory overstimulation start as soon as a vehicle starts moving, and continues while the vehicle is moving, affecting all animals in the moving vehicle. Animals experience stress potentially leading to fatigue and negative affective states such as fear and distress;
- The prevalence of group stress and resultant injuries is high with a variation in severity as not all pigs will be involved in fighting to the same extent. The duration of group stress depends on journey duration and may lead to fatigue.
- The prevalence of prolonged hunger is expected to be very high, as pigs – especially animals sent for slaughter – likely have been fasted before the initiation of the journey. The severity of hunger will develop further during the journey. Physiological indicators of hunger (e.g. liver

glycogen) as well as behavioural studies of post-journey eating behaviour, hunger is expected to be present after 12 h of feed deprivation, which (under current practice), for a large proportion of pigs transported to slaughter, corresponds to the initiation of the journey.
  - The prevalence of prolonged thirst may be high if water is not provided to the animals or they, for some reason, such as lack of familiarity or fear of other animals, are not able to drink enough water. So far, very limited documentation for proper intake of water, even in journeys fitted with drinkers, is available. Behavioural and physiological signs of thirst can be present after 8 h of transport. The severity is expected to increase with increasing duration, as the need for water becomes problematic for the animals. Prolonged thirst may lead to frustration, discomfort and dehydration.
  - The prevalence of resting problems is at least moderate, as resting problems may affect a large proportion of animals in a moving vehicle, even when space for lying is available. Duration depends on journey duration, and severity is expected to increase with increasing duration and may lead to fatigue.
  - The pain and/or discomfort from health conditions or injuries the consequences of which might be severe and will worsen over time during transport and may lead to suffering;

To conclude, during transport pigs will be exposed to a number of hazards, either on their own or in combination, leading to WCs. The amount of time the animals are exposed to these hazards is dependent on the journey duration.

4.5. Conclusions on journey breaks and control posts

- By definition, journey breaks remove the animals from the hazards that they are exposed to during transit, and allow them to recover from the associated WCs.
- The science underlying the duration of a journey break necessary to protect the welfare of pigs is ambiguous and further research is needed.
- It has not been clearly shown that it is possible for pigs to drink and rest according to their needs in a journey break on a stationary truck. This constitutes a gap in knowledge.

If pigs are to recover from the WCs experienced during transit they need to be unloaded from the vehicle for a sufficiently long period of time.

The highly relevant WCs for pigs during the CP stage are group stress, handling stress, heat stress, injuries, prolonged hunger, prolonged thirst, restriction of movement and resting problems.

Among the major hazards for animal welfare during the CP stage are mixing of unfamiliar animals, high effective temperatures, competition for resources such as feed and water, and lack of space.

- When CPs are used, animals must be unloaded and reloaded. These procedures involve hazards potentially leading to WCs such as handling stress, heat stress and sensory overstimulation (Section 3.4).
- In addition, CPs involve biosecurity risks as animals can be exposed to infectious diseases through direct or indirect contact with other animals and opportunistic pathogens.
- Across the categories of pigs typically transported on journeys involving journey breaks, the scientific focus on CPs has been very limited. This means that whether CPs in their current state fulfil their intended function is not known.
- For a stay in a CP or similar to be beneficial for the welfare of pigs during transport, a journey break needs to be long enough for each animal to eat and then drink and rest. Due to the tendency of pigs to develop motion sickness during transport, the animals should not be re-loaded immediately after eating. The time needed for the WCs from the transit stage to be mitigated by a stay at a CP constitutes a gap in knowledge.

4.6. Welfare of pigs when transported by air and rail

- For pigs, air transport involves only a small fraction of transported animals, and mainly breeding animals. Rail is the mode of transport used the least for pigs.
- The WCs, hazards, preventive and corrective/mitigating measures explained in the transport by road (Sections 3.3–3.6) also apply here. However, the EFSA experts identified additional concerns for pig welfare during air or rail transport, namely: high density confinement in crates, lengthy waiting times, extended periods of water and feed deprivation, variation in

microclimatic conditions, and potential exposure to noxious gases. Other factors that may lead to WCs are motion stress and loud noises.
- The available evidence to evaluate the welfare of pigs when transported by air or rail is very scarce. This constitutes a gap in knowledge.

4.7. Conclusions on specific scenarios

A) Transport of cull sows to slaughter

- Cull sows are often collected from different farms before transport to the slaughterhouse. This may increase the journey time and transport-related risks to animal welfare.
- The WCs, hazards, preventive and corrective measures explained for transport of pigs by road (Sections 3.3–3.6) also apply here, but when exposed to the hazards, the severity of the resultant WCs will most likely be higher for cull sows.
- In addition to the above, three major welfare concerns for the transport of cull sows to slaughter are (1) the fitness for transport, (2) the high sensitivity towards heat stress, and (3) the risk of group stress due to mixing with unfamiliar sows at one or more of the transport stages.
- No studies are available to allow a quantitative assessment of journey time for cull sows.
- Due to the general health impairment of a large proportion of cull sows, they may experience a higher risk of worsening of pre-existing health conditions (e.g. lameness), as well as a higher risk of new health conditions occurring during transport, than average pigs.
- Therefore, cull sows benefit from a restriction on journey duration compared to other categories of pigs. The current knowledge does not allow estimates of such a journey duration restriction, which constitutes a gap in knowledge.

B) Transport of special health status pigs

- The WCs, hazards, preventive and corrective/mitigating measures explained in the transport by road (Sections 3.3, 3.4 and 3.5) also apply here, with some extra additions due to the lack of possibility to unload the animals.
- The available evidence to evaluate the welfare of pigs during journeys where animals cannot be unloaded is very scarce. This constitutes a gap in knowledge.

5. Recommendations

The following section lists the recommendations of this Scientific Opinion.

5.1. General recommendations on the transport of pigs by road

- Protocols for the assessment of welfare of pigs during transport should be developed and validated, preferably involving aspects of pre-and post-transport housing and production systems, e.g. if animals are transported to or from intensive or extensive husbandry conditions.
- In order to have useful ABMs in animal transport, research should be carried out to develop them. This should include the identification and validation of technological solutions to assess welfare, aiming to assess outcomes more than input.

5.2. Recommendations for preparation of pigs before transport

- Protocols to assess animal welfare during the preparation phase, including scenarios characterised by repeated re-loading of animals should be developed and validated.
- The lack of scientific focus on the preparation phase means that the possibility to give evidence-based recommendations is limited. Based on general knowledge about pigs and the current practice, the following preventive measures are recommended in order to protect the welfare of pigs during this phase:
  - Avoid mixing of unfamiliar conspecifics.
  - Pigs should have unlimited access to water during the whole preparation phase. The type and number of drinkers should be adjusted to the category and number of pigs (taking on-farm recommendations as a starting point).

  - In the hours before loading onto a means of transport, pigs should be given the opportunity to rest, in terms of space, microclimatic conditions and possibility to avoid aggressive interactions with conspecifics.
  - In the hours before loading onto a means of transport, pigs should be kept in conditions allowing them to avoid solar radiation and providing microclimatic conditions corresponding to the TCZ of the specific pig category.
  - Periods of pre-transport fasting should be adjusted to the category of pigs and be appropriate for the planned journey duration, and in addition take into consideration whether pigs are transported for slaughter or for further fattening/breeding.
  - Until evidence-based thresholds are established, it is recommended to expose finishers being transported to a pre-transit fasting of less than 10 h. The time taken to load should be included within this 10-h period. For other pig categories pre-transit fasting should likely be shorter.
  - Research should be carried out to identify pros and cons of pre-journey fasting in terms of animal welfare. This should include examination of the effects of fasting duration and the establishment of guidelines, which could, e.g. take into account different types of feed in different relevant categories of pigs transported for slaughter as well as for fattening or breeding.

A) Fitness for transport

- In order to avoid WCs such as pain and discomfort, animals should be fit for transport. Guidelines based on ABMs for conditions leading to animals being unfit, including thresholds, should be established and validated. Among suggested candidate ABMs are lameness score, pyrexia, dyspnoea, ataxia, disorientation/abnormal behaviour, abnormal navel, wounds, aspect, demeanor, swollen joints, abscess, hernias, rectal and vaginal prolapse, late pregnancy, bone fractures, body condition score, eyesight deficiency.
- Risk associated with transport of animals with a number of conditions, potentially involving negative affective states during transport, such as pregnancy, should be examined.
- In order to avoid doubt and misclassification of animals in relation to fitness for transport, the concept should be properly defined, professional groups (including farmers, handlers, drivers, haulers, inspectors and veterinarians) should be well-educated, and questions on responsibility between the groups should be clarified.
- The effectiveness of measures to mitigate risk of transport of animals with reduced fitness should be examined.

5.3. Recommendations for loading/unloading of pigs during road transport

In order to minimise handling stress and other WCs during loading and unloading, handlers should be properly educated and trained.

Delays in loading and unloading should be avoided because of the increased exposure to hazards such as high effective temperatures, and the potential resultant WCs such as heat stress.

5.4. Recommendations for the transit of pigs during road transport

A) Microclimatic conditions

- Among the environmental factors affecting the heat load placed on pigs during transport, it is recommended to take temperature and at least humidity into account when pig welfare during transport is evaluated. The relationship between these can be expressed by different indexes. Further research should be carried out to assess costs and benefits of different choices of index.
- In order to reduce the risk of WCs due to exposure to high effective temperatures, the temperature inside vehicles transporting pigs should not exceed the UCT estimated to be 30°C for weaners, 25°C for finishers and 22°C for sows. However, it is recommended to keep temperatures below the upper threshold of the TCZ, estimated to be 25°C for weaners, 22°C for finishers and 20°C for sows, in order to protect the welfare of the animals during transport.
- Means of transport should be equipped with sensors recording microclimatic conditions as close as possible to the position of the animals in the vehicle, and at several locations to

include hot as well as cold spots, and representative points in between, thereby allowing monitoring of the microclimate (preferably a combination of temperature and humidity) of the load, and the adjusting of the ventilation if the conditions exceed the comfort zone levels. Technical issues (e.g. accuracy, maintenance, placement, reliability and calibration) relating to this improved approach should be clarified.

  - Future research is recommended in the development of systems to maintain the microclimatic conditions in stationary as well as moving vehicles across different compartments and deck heights, when using forced and natural ventilation. Research should include possibilities to maintain low temperatures by, e.g. air conditioning.

B) Space allowance

- In order to protect the welfare of pigs during transport, it is recommended to use the allometric equation $A = kW^{2/3}$ to calculate the minimum space allowance.
- Until evidence-based thresholds are established for the space requirements of pigs to be able to adjust to acceleration events, it is recommended that the minimum space allowance is based on a k-value of at least 0.027, thereby allowing pigs to be able to lie down during journeys. This recommendation applies to all categories of pigs transported in groups, and takes as a prerequisite that pigs are transported under microclimatic conditions corresponding to what is recommended in Section 3.5.3.1 of this Scientific Opinion.
- Research is needed to establish evidence-based thresholds for vertical space, in order to prevent hazards such as reduced ventilation, lack of ability to move around and lack of space for natural movements, and thus avoid WCs such as heat stress and restriction of movement.
- Future research is recommended in the following areas:
  - Determine the effect of different space allowances, as based on the biological functions of pigs during transport on the behaviour and clinical condition of different pig categories during transport. In particular, research should explore the ability of pigs to lie, to stabilise themselves, to thermoregulate and perform social behaviours (including fighting) during transport of long and short duration.
  - Determine the required space and design of the vehicle, including the location of drinkers, the drinker type and the pig to drinker ratio for pigs to drink during transport. Focus should be on water intake by the animals and on potential consequences of water wastage in terms of animal welfare.
  - Determine vehicle design components, including the deck height and ventilation capacities to protect the welfare of different categories of pigs

C) Journey time

- The number and the severity of hazards that animals are exposed to during transport influence the resultant WCs, but on the basis of evidence on continuous WCs involving stress and negative affective states, for the benefit of animal welfare, the journey duration should be kept to a minimum.
- To limit the impact of transport on animal welfare, in an effort to reduce the exposure to hazards and related WCs, continuous, progressively developing and sporadic, it is recommended to consider that:
  - Animals experience motion stress and sensory overstimulation throughout the entirety of the journey potentially leading to fatigue, fear and distress;
  - Group stress starts as soon as pigs are mixed and continues during the journey and may lead to fatigue;
  - The pain and/or discomfort due to health conditions and injuries might be severe and will worsen over time during transport;
  - Resting problems severity is expected to increase with increasing duration and may lead to fatigue;
  - Behavioural and physiological changes that are likely to be associated with thirst have been identified after 8 h of transport, even when drinkers are fitted to the transport vehicle;

  - Behavioural and physiological changes indicative of hunger can be present after 12 h of feed deprivation. Depending on the pre-transport fasting this may correspond with the early hours of a journey.
- Future research is recommended in the following areas:
  - Investigation of relationships between journey time, journey conditions and ABMs considered to reflect affective states of pigs for all animal categories, including knowledge about the progressively developing WCs and their changes over time. Such research could inform the appropriate limits on journey duration if the recommended conditions of temperature and space are not fulfilled.
  - Development of transport practices by which the risk of motion sickness can be reduced, and pre-journey fasting of pigs therefore can be avoided.

5.5. Recommendations for journey breaks and control posts

Based on general knowledge about pigs and the current practice, the following is recommended to protect the welfare of pigs during this transport stage. New scientific knowledge may lead to adjustments of these.

- Avoid mixing unfamiliar pigs in a CP.
- The microclimatic conditions in the CP should allow pigs to be kept in their TCZ throughout their stay.
- In order to cover the basic needs of pigs, conditions regarding space and access to enrichment laid down in the legislation regarding pig husbandry conditions are recommended as the starting point – for CPs in and outside EU. In addition, future regulation and recommendations on these matters, regarding pig housing on farm, should also apply for CPs.
- When feed is provided, all pigs should be able to eat at the same time.
- Access to drinkers should be easy at all times.
- Animals showing signs of weakness or disease should be inspected and treated accordingly. Animals unfit for further transport should not follow the consignment at re-loading, but be slaughtered, treated or euthanised according to the prognosis of their condition. Contingency plans should be in place for injured and sick animals.
- Pigs should not be overfed before re-departure.
- Pigs should not enter buildings that have not been cleaned properly, and are not dry.
- Until evidence is available, it is recommended that the number of times that pigs stay in a CP should be as low as possible.
- Until evidence-based thresholds are established for the duration of rest periods, alignment with the current 24 h period is recommended.
- Future research in the following areas is recommended:
  - Research is needed to examine whether CPs fulfil their function, and how they should be designed and managed in order to protect pig welfare.
  - Research is needed to determine the effects on pig welfare of the duration of a stay at a CP as well as determine WCs of repeated stays at CPs.

5.6. Recommendations for the transport of pigs by air and rail

- Until evidence-based thresholds are established for these means of transport, alignment with the recommendations for road transport is recommended.

5.7. Recommendations on specific scenarios

A) Transport of cull sows to slaughter

Due to the similarity in the WCs and hazards, alignment with the recommendations for road transport for preparation, loading/unloading and transit microclimatic conditions and space allowance (see Sections 3.3, 3.4, 3.5.3.1, 3.5.3.2 and 3.6) is recommended.

In order to avoid WCs, such as pain and discomfort, animals should be fit for transport. Guidelines based on ABMs for conditions leading to animals being unfit, including thresholds, should be established and validated.

In order to avoid doubt and misclassification of animals in relation to fitness for transport, the concept should be properly defined, professional groups (including farmers, stockpersons, drivers, haulers, inspectors and veterinarians) should be well-educated, and questions on responsibility between the groups should be clarified.

If these animals are fit for transport, the journey to a slaughterhouse should be kept to a minimum, be direct and not involve any unloading and reloading at any interim premises. Sows should be slaughtered as soon as possible upon arrival.

If these animals are not fit for transport and are without the prospect of recovery in a reasonable period of time, they should be killed on farm as soon as is possible.

B) Special health status

The recommendations for road transport (see Sections 3.3, 3.4 and 3.5) are applicable in this context therefore it is recommended to apply them, except for journey breaks, as these do not apply to this scenario. Research is needed to develop vehicles and procedures, including stationary resting periods, to ensure that the welfare of pigs during this type of transport is protected.

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Abbreviations

ABM	animal-based measure
AST	aspartate aminotransferase
bpm	Breaths per minute
CK	creatine kinase
EKE	Expert Knowledge Ellicitation
HR	heart rate
HRV	heart rate variability
LCT	lower critical temperature
PRE	preventive measure
RH	relative humidity
RR	respiratory rate
RT	rectal temperature

SAA	serum amyloid A
TCZ	thermal comfort zone
THI	temperature–humidity index
TNC	thermoneutral zone
TRACES	TRAde Control and Expert System
TRPB	transport-related problem behaviour
UCT	upper critical temperature
WC	welfare consequence

Appendix A – Template used during the selection of the highly relevant welfare consequences

Name	Example			
Animal species	Example			
Animal type	Example			
Husbandery system	Example			
Code	**1**	Clearly relevant		
	32	Clearly not relevant		
	33	Not applicable		
	2 to 31	**Please rank the remaining WCs**	VVV	
ID	**Abbr**	Welfare Consequence	**Ranking**	Binding
B03	**SCS**	Group stress	0	0
H03	**HEA**	Heat stress	1	0
H04	**CLD**	Cold stress	1	0
B02	**RSP**	Resting problems	1	0
B06	**GFS**	Motion Stress	1	0
H01	**HNG**	Prolonged hunger	1	0
B01	**MOV**	Restriction of movement	1	0
B04	**VAS**	Sensory Overstimulation	1	0
B05	**HNL**	Handling stress		0
B09	**CMF**	Inability to perform comfort behaviour		0
B12	**EXP**	Inability to perform exploratory or foraging behaviour		0
H02	**H2O**	Prolonged thirst	1	0
H05	**LOC**	Locomotory disorders (including lameness)		0
H06	**SKL**	Skin lesions and wounds		0
H10	**RES**	Respiratory disorders		0
H12	**GED**	Gastro-enteric disorders		0
H15	**MTB**	Metabolic disorders		0
H16	**MUS**	Muscle disorders		0
H17	**UMB**	Umbilical disorders		0
B08	**SEP**	Separation stress	32	0
B16	**PLY**	Inability to perform play behaviour	32	0
H07	**MAN**	Pain resulting from management procedures	32	0
H08	**BNL**	Bone lesions (incl. fractures and dislocations)	32	0
H09	**SKD**	Skin disorders (other than pododermatitis or skin lesions)	32	0
H11	**EYE**	Eye disorders	32	0
B07	**ISO**	Isolation stress	33	0
B10	**WSX**	Inability to perform sexual behaviour	33	0
B11	**USX**	Inability to avoid unwanted sexual behaviour	33	0
B13	**MAT**	Inability to express maternal behaviour	33	0
B14	**SUC**	Inability to perform sucking behaviour	33	0
B15	**CHW**	Inability to chew and ruminate	33	0
H13	**RPD**	Reproductive disorders	33	0
H14	**MAS**	Mastitis	33	0
Please sort this table by the "Ranking" and complete the "Binding" (No. of cells with same rank)				