11 TRANSPORTATION

Michael S Cockram

Introduction

The potential welfare issues associated with transporting farmed animals include stress, hyperthermia/hypothermia, injury (pain), fatigue, motion sickness, disease (sickness), hunger, and thirst. Whether welfare issues arise during transportation will depend upon the type of animal (e.g., species, age, and condition), their fitness for transport, the quality of the journey (including vehicle design, stocking density, ventilation, the standard of driving, and quality of the road), journey duration, the environmental conditions, and the associated handling and management of the animals. This chapter reviews the risk factors that can affect the welfare of animals when they are transported and the measures that can be used to mitigate potential welfare issues.

Transportation poses risks to animal welfare, but the prevalence, severity, and types of issues that farm animals experience during transport are contentious. There is a disparity between the judgments of campaigning organisations and those of industry on the perceived welfare consequences of transportation. When animals are transported, they are exposed to multiple factors that can influence their affective state, cause physiological and behavioural changes and sometimes injury and pathological changes. The transport of animals is not a natural process, and in most cases, it will be associated with novelty and stress. However, severe welfare issues are not an inevitable consequence of transportation. Many animals arrive at their destination without overt signs of welfare issues, are healthy and in good condition. There are economic pressures on the industry to avoid mortality, morbidity, poor meat quality, weight loss, food safety, and biosecurity issues that can sometimes be associated with transportation. Therefore, there is some degree of synergy between the standards required for optimal productivity and those for animal welfare. That said, if transport is not undertaken well, animals can experience pain, fear, distress, fatigue, and prolonged hunger and thirst. These adverse effects can occur when occasional issues arise. However, there are commercial pressures on the manner in which animals are routinely transported, and these can affect the quality of the journey. There are costs associated with optimising some welfare conditions, for example, by careful handling and driving, providing environmental control, reducing stocking density, and providing feed, water, and rest at frequent intervals.
Transportation reasons

The main reasons for transporting farmed animals are:

- Slaughter;
- Transfer between production units during stages of production;
- Sale at an auction market/saleyard;
- Transfer of breeding animals;
- Movement to areas with improved access to feed and/or water.

Most farm animals that are reared for meat and those that are slaughtered after they are culled following a period of breeding or production are transported from a farm to a place of slaughter. Many breeding animals have high value and are transported in superior conditions. The intensification of production has increased the number of times that many animals are transported. For example, animals can be born in one location, fattened/reared in one or more locations and then slaughtered in a specialised facility. Some journeys can be long and complex and can involve multiple stages and destinations, sometimes with export between countries.

Welfare concerns

During transport, animals can be exposed to a range of potential stressors, including food and water deprivation, thermal extremes, physical injuries, motion sickness, mixing with unfamiliar animals, close confinement, and novel experiences (Fisher et al., 2009; Schwartzkopf-Genswein et al., 2012). If a journey is undertaken according to best practice and in compliance with all aspects of any regulations designed to protect the welfare of animals in transit, many animal welfare problems would either not be expected to occur or would be minimised. A range of behavioural and physiological measurements have been used to assess the responses of animals to transportation. However, changes in some of these variables do not necessarily reflect reduced welfare. Other than monitoring behaviour, there are few animal-based welfare assessments that can be used during a commercial journey. The main animal-based assessments are made during and after unloading (Cockram, 2020). The welfare implications of transport are assessed from observations of behaviour, physiological and biochemical measurements, mortality, morbidity, injury, and carcass characteristics (EFSA, 2011, Table 11.1). The occurrence of some meat quality issues, such as Pale Soft Exudative and Dark–Firm–Dry/Dark cutting meat, is related in part to handling and transport (Adzitey and Nurul, 2011). However, they do not have the specificity to be used to assess animal welfare.

When considering the implications of journeys, it is important to consider each risk factor, their interactions and the multiple stages that can be part of a transport continuum. Whether welfare issues arise during transportation will depend upon the type of animal, their fitness for transport, the quality of the journey, the environmental conditions, and the associated handling and management of the animals.

The ability of animals to cope with handling and transport varies between:

- Animals that respond differently to periods of feed and water deprivation, e.g., between ruminants that have potentially larger stores of water and feed in their rumen than monogastrics that have a smaller stomach, and between unweaned and weaned animals;
- Animals that respond differently to heat stress due to differences in their effectiveness to lose heat via respiratory evaporative water loss and sweating, and to cold stress due to differences in their amounts of fat and coat insulation;
Table 11.1 Potential welfare outcomes of transportation, their main risk factors, and common methods used in their assessment

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Main risk factors</th>
<th>Examples of methods of assessment</th>
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<tbody>
<tr>
<td>Hyperthermia and heat stress</td>
<td>inadequate ventilation, high stocking density, high ambient temperature and humidity</td>
<td>behavioural and physiological responses (increased respiration rate, panting and sweating), raised body temperature, mortality</td>
</tr>
<tr>
<td>Hypothermia and cold stress</td>
<td>low ambient temperature, wet or diminished coat insulation, air movement/wind</td>
<td>behavioural responses (huddling, shivering), lowered body temperature, mortality, frostbite</td>
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<tr>
<td>Injury</td>
<td>manual handling, contact with structures, animal interactions, loss of stability due to vehicle acceleration and slippery floors</td>
<td>skin cuts and lacerations, post-mortem bruising, post-mortem bone fractures, lameness and non-ambulatory conditions, plasma creatine kinase activity</td>
</tr>
<tr>
<td>Fatigue</td>
<td>prolonged standing, muscular exertion to brace against acceleration and to make frequent foot adjustments, inadequate rest, exhaustion of body energy reserves</td>
<td>behavioural responses (reduced responses to fear and other external stimuli, resting), non-ambulatory conditions, blood and tissue measurements indicative of exhaustion of body energy reserves and accumulation of metabolites (lactate)</td>
</tr>
<tr>
<td>Hunger</td>
<td>prolonged periods without access to feed, fasting before transport</td>
<td>behavioural responses (vocalisation, reduced latency to eat, increased feed consumption, investigation of non-food materials), blood and tissue measurements indicative of utilisation of body energy reserves: liver glycogen concentration, raised plasma concentrations of β-hydroxybutyrate and free fatty acids, and reduced blood glucose concentration (hypoglycaemia)</td>
</tr>
<tr>
<td>Thirst and dehydration</td>
<td>prolonged periods without access to drinking water, high ambient temperature consumption of feed</td>
<td>increased drinking, behavioural responses (reduced latency to drink), blood variables indicative of decreased water content: increased plasma osmolality and plasma total protein concentration, reduced body weight, skin tenting, sunken eyes</td>
</tr>
<tr>
<td>Stress</td>
<td>fear of humans and other animals, novelty, noise, acceleration and vibration, light and odours</td>
<td>raised concentrations of plasma glucocorticoids and catecholamines, increased heart rate and heart rate variability.</td>
</tr>
<tr>
<td>Illness</td>
<td>mixing with animals from different sources, exposure to pathogens from fomites immunosuppression, poor air quality</td>
<td>behavioural responses, clinical and post-mortem examinations and laboratory tests</td>
</tr>
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Animals that respond differently to changes in social grouping (due to differences between species and rearing conditions), e.g., some fight and use teeth or horns to injure each other;

Animals that are different in size as this affects how they are manually handled and their centre of gravity affects their response to changes in acceleration;

Animals in different physical condition due to their fitness as a result of injury, disease, weakness, genetic traits for productivity, and drugs given;

Different rearing conditions as this can influence experience of exposure to stressors and humans;

Different physiological states, such as lactation and pregnancy (Transportation Code of Practice Scientific Committee, 2018).

Species-specific information on handling and transportation can be found in Grandin (2019), and online guides to good practice are available, e.g., Spoolder (2019).

**Transportation modes**

**Land transport**

**Road transport**

The most common mode of animal transport is by road. Vehicles designed for the transportation of animals usually consist of an integrated cab and livestock compartment or an articulated vehicle consisting of a vehicle/tractor attached to one or more trailers. In less regulated areas, animals can be transported on open trailers, trucks, bicycles, and motorcycles. The livestock compartment normally consists of a chassis-mounted box that can be single tier or multi-tier, where animals are carried on several floors or decks. Internal ramps within a vehicle are often steep. Especially in a multi-decked vehicle, it is important that the deck height is sufficient for the animals to stand in their normal position without the deck coming into contact with any part of the animal, and there is adequate airflow over the animals. Many vehicles or trailers have sides that are enclosed with ventilation openings and a roof to provide protection from the external environment (preferably reflective and insulated). The walls can be thermally insulated, but in situations where protection from cold conditions is not required, the compartment can be more open, with sides consisting of a fence-type construction. For ease of cleaning and durability, most livestock vehicles are constructed of aluminium and steel. There should be no sharp edges or protrusions, and sheeting is used to provide a smooth surface to prevent bruising. Internal partitions across the width of the vehicle, adjustable for different sizes, numbers, and types of animal, are used to reduce movement due to vehicle acceleration and to separate groups. Vehicle exhaust stacks should be at least as tall as the roof, otherwise, diesel fumes can enter the livestock area. The floors can be constructed of pressed metal sheeting or a metal grid to provide a non-slip surface. In some countries, bedding materials such as sawdust, wood shavings, straw, and sand are used to absorb urine and faeces, provide traction to reduce slipping, comfort, and thermal insulation. When animals are transported in containers, the containers are normally stacked on a flat-bed trailer that is completely or partially open on the lateral sides of the vehicle.

**Rail transport**

Transport by rail (Bischop, 1961; Sutton, 1961) is no longer a common mode of transportation and is restricted to specific locations within some countries. However, there is potential for the expansion of rail transport and a rail journey is likely to be conducted at a relatively constant speed with fewer stops than on a road journey (Woodhead et al., 2016). Rail transport can be
used if handling facilities such as loading ramps are available at the railheads and there are direct links to the common destinations.

**Walking**

Droving/walking/trekking of livestock is a traditional mode of transportation and still occurs in some countries and in specific locations, such as during transhumance in mountain regions. However, walking is only used where the infrastructure for road transport is inadequate; the journeys are short or insufficient resources are available to use road transport. It is a slow method of transport and exposes the animals to risks such as accidents, predation, toxic plants, poor walking surfaces, infectious diseases, and environmental extremes. Arrangements need to be made for opportunities for grazing, watering, and overnight rest. Some animals can experience weight loss, muscular damage, injury, starvation, dehydration, and exhaustion.

**Sea transport**

Livestock are transported between countries on long journeys by sea in specialist vessels. As some journeys can last for days or weeks, arrangements are made for the daily care and management of the animals. Welfare issues can occur if sea and weather conditions are extreme. Sheep and cattle are transported on long sea journeys from Australia to the Middle East. Some sheep die during these journeys due to heat distress, starvation from failure to eat the pelleted food offered during the journey, and salmonellosis. The animals can also experience discomfort from the accumulation of ammonia and from the motion of the ship (Phillips and Santurtun, 2013). Many shorter journeys are conducted using roll-on-roll ferries where the livestock remain in the vehicle. Although there is forced ventilation below deck, this does not cause sufficient air movement within the vehicles. Extra adjustable ventilation openings are required, and for long journeys, the stocking density may need to be reduced (Watts, 1982).

**Air transport**

Air transportation is expensive and mainly restricted to high-value animals and day-old chicks. The International Air Transportation Association (IATA) (2021) have produced guidelines for the transport of animals by air. The animals are normally placed in containers. Their stability can be affected by turbulence, take-off, and landing. Air-conditioning units should be available at departure and on arrival (Watts, 1982; Le, 2012; Collins et al., 2020).

**Preparation before transport**

Fasting prior to transport for slaughter is practised to reduce faecal contamination and stomach and intestinal distension that can pose a risk of inadvertent puncture/rupture during evisceration (Hogan et al., 2007). Fasting pigs and broilers before transport can also reduce the risk of mortality during journeys in warm weather (Averos et al., 2008; Caffrey et al., 2017). Vaccinating and pre-weaning calves before they are transported on a long journey reduces mortality and morbidity (especially respiratory disease) after arrival (Earley et al., 2017).

**Fitness for transport and compromised animals**

The fitness of animals for their intended journey must be assessed before loading and many countries have regulations that define when animals are considered to be unfit for the intended
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journey. Examples of animals that are unfit for transport include those that are sick, injured, weak, disabled, or fatigued; those that are unable to stand unaided and bear weight on each leg; those in poor body condition, are pregnant and likely to give birth, neonatal animals and those with a condition that indicates that they cannot be transported without suffering (OIE, 2018). In some cases, animals arrive unfit at their destination because their health deteriorated during the journey, and in others, the animals may have had pathology that was not readily apparent before loading. Issues can arise when different stakeholders have different views on the criteria that make an animal unfit for transport (Dahl-Pedersen et al., 2018).

Compromised animals with major pathology are likely to experience pain, systemic illness, and have reduced physiological function, e.g., to respond to changes in environmental temperature and undertake physical movement (walking on and off the vehicle and maintaining stability). In addition, their physical condition (e.g., low body condition score, weakness, and chronic disease) can increase their vulnerability to injury from handling and to extended periods without feed, water, and rest. Animals that are not in good health are more likely to become fatigued, injured, non-ambulatory, or die during transport (Cockram, 2019).

Compromised and vulnerable animals require additional care, such as restricting the duration of the journey and ensuring that the animals are transported directly to their destination; individual loading and unloading without having to negotiate internal ramps; loaded last and unloaded first; segregated on the vehicle; provided with additional bedding; not transported in extreme thermal conditions, and given increased provision of feed and water. Lactating animals require drying-off before a journey; otherwise, they will need regular milking to avoid udder engorgement and discomfort. Of particular concern is the transport of cull animals that are sent for slaughter after a period of breeding or production of milk/eggs. These animals should be transported while they are still fit, or they should be killed on-farm for consumption or disposal (Cockram, 2021). If end-of-lay hens are transported to slaughter rather than killed on-farm, this can cause severe welfare issues. The layers are susceptible to bone fractures during handling and cold conditions as a consequence of reduced feathering (Newberry et al., 1999; Vecerkova et al., 2019).

Handling

Stress during handling and the risk of physical injury can be minimised by ensuring that the facilities are well designed and the handlers trained and supervised. Animals can be stressed by movement from their normal pen and mixing before or at the time of loading. Before loading, animals destined for slaughter may need to be segregated from the rest of the group, weighed, and their condition assessed. Some animals require identification, such as ear tagging or branding for traceability, and this can involve additional handling and discomfort. In most circumstances, it is preferable to segregate the following during handling and transportation: different species; significantly different sizes or ages; adult breeding males; sexually mature males from females; animals with horns from animals without horns; animals hostile to each other; and tied animals from untied animals. Animals that have been handled previously are easier to handle than those that have never been handled, and the temperament of the animal can affect the ease of handling. Tools such as panels, flags, and rattles can be used to encourage and direct the movement of the animals. However, animals should not be hit or kicked; pressure should not be applied to any particularly sensitive part of the body, and they should not be lifted or dragged by their extremities. Instruments that administer electric shocks (goads/prods) should be avoided as far as possible. Grandin (2020) has pioneered the use of handling methods that consider the herding and/or flocking behaviour of animals, movement of animals in small groups, flight zones and
points of balance, field of view, depth perception, visual and auditory distractions, movement towards light, and avoidance of slippery floors. Performance standards can be established in which numerical scoring is used to evaluate the use of driving instruments and the percentage of animals slipping or falling.

**Loading and unloading**

The assembly/holding areas used before loading should be designed to provide protection from the weather, separate social groups, and, if the animals are kept for an extended period, opportunities for rest, feed, and water. The loading facilities should be designed, constructed, maintained, and operated to minimise the risk of injury and to facilitate movement of the animals. Larger animals walk onto the vehicle; some are lifted onto the vehicle; poultry and small mammals are normally loaded onto the vehicle in containers. Animals can be loaded using (a) a ramp that is integral to the vehicle or via an external ramp that can be longer and not as steep; (b) a loading bridge where the animals can walk onto the vehicle without having to walk up an incline; (c) an elevator or hydraulic lift that allows a group of animals to walk into a pen or the floor of the vehicle that is then raised to the relevant vehicle deck level; (d) manual catching and placement into a container that is then loaded onto the vehicle; or (e) manual catching and placement directly onto the vehicle. Ramps, bridges, gangways, and lifts should be non-slip and have sides, railings, or some other means of lateral protection. Ramps used for loading should have the minimum possible incline. Where the slope is steep, the ramp should be fitted with foot battens or steps.

Broiler chickens are usually caught manually from the barn floor then carried to a receptacle consisting of a crate or module placed either inside or outside of the barn. The container is carried out of the barn either manually or via a forklift truck. The manner in which the birds are carried and placed in the container affects the risk of injury and mortality (Cockram and Dulal, 2018). The stocking density in the container is adjusted according to the live weight of the birds and the thermal conditions. Mechanical catching using a machine to collect the birds from the floor and move them into a receptacle for loading onto a transport trailer is used in some countries. In some systems, a conveyor belt is used to load the birds.

Loading can sometimes be prolonged, and some vehicles have to wait before unloading at the destination. During this time, ventilation may be inadequate and external mechanical ventilation using banks of fans can be beneficial to reduce the risk of heat stress. On arrival at the destination, some animals may have become non-ambulatory because of injury, a metabolic condition or weakness. Large non-ambulatory animals should be killed on the vehicle and not unloaded.

**Transportation effects**

**Stress**

Transport involves exposure to many simultaneous stressors. Stress responses are affected by interactions between genetics, experience, and the manner in which animals are handled and transported (Fisher et al., 2009). Stressors during handling and transport include those that initiate fear, such as novel stimuli, unpredictable stimuli (such as noise, motion, and acceleration), proximity to humans, other animals (especially if in mixed social groups), handling systems that separate/isolate animals from other members of their group, moving animals too fast, exposure to heat and cold, and restraint. Some breeding practices have made certain strains more susceptible to stress, heat, and exercise (Grandin, 2021).
Injury

Injuries such as cuts, lacerations, bruising, fractures, dislocations, and trauma to existing lesions can occur during handling and transport. These can be caused by design flaws such as protrusions, slippery floors and moving animals too fast, resulting in slips and falls, physical force used by a handler, either directly or with a tool, aggressive interactions and mounting between animals (especially in mixed social groups), and by movement caused by vehicle acceleration resulting in loss of stability during the journey. Post-transport assessment of injuries to benchmark the percentages of animals with bruising, fractures, and dislocations provide an indication of the number and severity of physical insults sustained during handling and transportation.

Hunger and thirst

Animals can be exposed to long periods without feed and water, and this predisposes them to hunger and thirst. Feed and water in the rumen can provide ruminants with a source of energy and water, but other animals are more vulnerable, especially in hot or cold conditions. If feed and/or water is restricted, the animals do not eat and/or drink enough before transport, during a journey, or while at an intermediate stop, the cumulative effect is loss of weight, and some animals will be at risk of dehydration and some will show signs of significant mobilisation of body energy reserves.

Fatigue

Fatigue during transport may result from long periods of standing, muscular tension required to brace the body in response to vehicular movements, and frequent limb movements as a result of a loss of balance. Exhaustion can reduce the capacity of an animal to respond to vehicle movement and predispose to injury. Muscle fatigue can be associated with a depletion of muscle energy stores, such as glycogen, the accumulation of metabolites, and muscular damage. However, clear evidence of fatigue after a long journey in terms of muscle exertion and damage and a short latency to lie down is not always apparent (Fisher et al., 2009).

Infectious disease

Mixing animals from different sources increases the risk of contact with infected animals and/or materials. Vehicles and containers need to be cleaned and disinfected after every journey. There is an increased susceptibility to infection and disease if the animals are “stressed” by the journey with increased shedding of pathogens and immunosuppression. Prior vaccination, segregation, and quarantine of transported animals at the destination may be necessary. When animals are exported between countries, considerable care is required to follow biosecurity protocols and to complete any necessary testing, inspection, and documentation.

Mortality

Some animals are dead on arrival, and others die within a few days of a journey. The risk of mortality tends to be greatest in cull animals, poultry, and pigs. Risk factors for mortality in poultry are heat and cold stress, trauma, and disease. The mortality risk in pigs is affected by the genotype, fasting, and heat stress.
Thermoregulation

During transportation, animals can be exposed to thermal environments that can cause thermal stress, and sometimes it can exceed their thermoregulatory capacity, and they can experience hyperthermia and hypothermia. Animals can die from hyperthermia if the conditions are too hot and humid or from hypothermia if the conditions are too cold, the animals are wet and cold, or they have lost some of their coat insulation, and they are exposed to wind. The conditions inside a vehicle can be very different from those outside the vehicle. The internal environment is affected by the metabolic heat and moisture produced by the animals, the efficiency of the ventilation system, the external environment, vehicle movement and vehicle insulation. High stocking density, poor ventilation, exercise, stress, and movement from their established environment can predispose animals to thermal environments that exceed their capacity to maintain homeostasis. Major differences exist in the thermoneutral range of transported farmed animals and their ability to avoid thermal stress. Species vary in their surface area to body mass ratio and their consequential rate of heat exchange with their environment. Age, body condition, type of digestive system, duration of fasting, and presence of fat can affect the energy reserves available to increase heat production in cold conditions. The ability of animals to thermoregulate can also depend on the space available to move and adjust their posture. There are major differences between species in their relative abilities for evaporative heat loss via respiration and sweating. For example, pigs and poultry do not have sweat glands that increase sweating in response to raised temperatures.

Ideally, animals should be transported within their thermal comfort zone, i.e., the range of effective environmental temperatures where an animal is able to thermoregulate with the least behavioural and physiological effort by changing exposed body surface, tissue insulation (sensible heat loss), and latent (evaporative) heat loss without panting (EFSA, 2004). A temperature monitoring and recording system, as well as a warning system to alert the driver when temperatures in the animal compartments reach a maximum or minimum limit, is beneficial.

Heat stress

The greatest risk of heat stress occurs at high temperatures and high humidity. As the ambient temperature approaches body temperature, sensible cooling becomes less effective, and the animal relies increasingly on evaporative cooling. In response to heat, all farmed animals increase their respiratory rate and some, such as cattle and sheep, can increase heat loss by sweating. The ability of animals to lose heat via the evaporation of water is dependent on a temperature and vapour pressure gradient. As humidity increases, the effectiveness of evaporative cooling decreases. The temperature and humidity within a vehicle are dependent on the weather conditions, the number of animals within the vehicle and the efficiency of the ventilation to remove heat and moisture. A forecast of the temperature-humidity index can be used to assess the risk of heat stress during transportation.

Cold stress

During journeys in cold conditions, the animals (especially poultry and young pigs) require protection from cold external temperatures, and it is essential that the animals do not become wet or exposed to excessive air movement. In cold conditions, protection from excessive air movement and precipitation involves the use of protective barriers (e.g., screens, curtains, and tarpaulins) around part or all of the vehicle/trailer or the partial closure of ventilation openings by use of flaps and boards. Unfortunately, this reduces the ventilation, and the
internal trailer temperature rises. In extremely cold conditions, this temperature rise can be beneficial in that it can raise the internal temperature above potentially lethal cold external temperatures. However, in a closed or partially closed ventilation configuration, internal thermal cores consisting of pockets of raised temperature and moisture from the animals can occur at one or more locations within the vehicle (Kettlewell et al., 1993; Mitchell and Kettlewell, 1998). Especially in poultry, if the internal temperature and humidity within areas in the core of the vehicle rises too high, some of the animals can experience hyperthermia, even though the external temperature is so low that it would otherwise have caused hypothermia (Mitchell and Kettlewell, 1998). In cold conditions, the air entering the vehicle through air inlets is at a low external temperature and might be accompanied by moisture and excessive air movement. The parts of the vehicle or vessel near air inlets and those on the sides of the vehicle close to the cold external temperature can expose some animals to a risk of hypothermia of sufficient severity to cause death. If an animal cannot move away from the side of the vehicle, it may also be susceptible to frostbite and freezing to metal surfaces. Adding extra bedding, such as straw, when the temperature is low can provide increased floor insulation, but wet bedding should be removed to avoid freezing.

Factors affecting journey quality

Ventilation

Natural ventilation

An efficient ventilation system removes the heat and moisture produced by the animals and replaces it with external air. It should be designed, constructed, and maintained in such a way that, at any time during the journey, whether the vehicle is stationary or moving, it is capable of maintaining a thermal environment that meets the animals’ requirements. Most livestock vehicles are ventilated by natural/passive ventilation. Airflow is provided through apertures along the sides (and sometimes the roof) of the compartment, and this allows air exchange between the internal and external environment. Air movement can also provide some convective cooling. The control of natural ventilation is achieved by the driver opening and closing ventilation apertures while the vehicle is stationary. Most air movement is caused by external pressure changes produced by a moving vehicle. As the vehicle moves, air passing over the front edge of the container separates from the vehicle and creates an area of low pressure (suction). The airflow tends to re-attach along the length of the vehicle and enter through the rear openings. Air usually moves forward within the livestock area and leaves through ventilation apertures near the front of the vehicle. Airflow is dependent on vehicle speed, wind direction, vent area, and the degree of obstruction caused by the animals (Gilkeson et al., 2009). In climates where the risk of exposure to cold is low, the vent area can be greater. There should be sufficient space inside the compartment and at each of its levels to ensure that there is adequate airflow above the animals and between containers. When the vehicle is stationary, airflow within the vehicle is dependent on either wind or the stack effect. Convective airflow from the heat of the animals is responsible for thermal buoyancy (the stack effect). During stationary periods, the ventilation is often inadequate, and in hot weather, parking for prolonged periods in direct sunlight or close to obstructions to wind should be avoided. Parking vehicles at right angles to the wind direction is optimal. Effective ventilation is also important to maintain air quality. High concentrations of ammonia, particles, and microorganisms can accumulate during a journey and increase the risk of health and welfare issues.
Mechanical ventilation

As passive ventilation may not always provide consistent, effective ventilation, some vehicles have mechanical ventilation. Mechanical ventilation is especially useful for stationary periods. The direction of airflow created by the fans should be used to enhance the natural airflow within the vehicle caused by the forward movement of the vehicle. Extraction fans near the front and air inlet apertures near the rear of the vehicle provide the most effective arrangement. In case of mechanical failure, a fan ventilated vehicle should have the capability of opening sufficient side apertures to enable emergency natural ventilation (Kettlewell et al., 2001). When livestock are transported by sea in a vessel that depends on mechanical ventilation there should be a back-up system to prevent heat distress (Schultz-Altmann, 2008).

Motion, driving, and road surface

During transport, animals are exposed to acceleration from vehicle movement. Acceleration is the rate of change in the velocity of an object (whether it is forward acceleration or deceleration) and is affected by the balance of forces that act on an animal and its mass. Acceleration occurs in three axes (longitudinal, lateral, and vertical) and consists of vibrations and shocks (Gebresenbet et al., 2011). Shocks are short-duration, high-amplitude acceleration events that occur randomly and are produced in response to a driving event, such as braking, cornering, or running over a pothole. Random, high-magnitude acceleration events (shocks) pose the greatest risk of loss of postural stability (Tarrant, 1990). Vibration represents background acceleration. If the vibration is close to the whole-body resonant frequency, it is aversive, stressful, can reduce resting behaviour, and in pigs cause motion sickness (Santurtun and Phillips, 2015). The roughness, undulation, and curvature of roads, the type of vehicle suspension system, and the manner in which the vehicle is driven can affect the acceleration experienced by the animals. This can affect their stability and ability to rest (Cockram and Spence, 2012).

Stocking density

The stocking or loading density refers to the number or live weight of animals within a specified area of floor space. The space allowance can be quantified as the floor area per animal, but the relevant live weight range must be specified. Allometric equations \( kW^{2/3} \) where \( k \) is a constant and \( W \) represents live weight are used to estimate the space that a stationary animal occupies as a consequence of its mass (Petherick and Phillips, 2009). A \( k \) value of at least 0.02 is required, but if all of the animals within a pen need to lie down simultaneously, a \( k \) value of at least 0.027 is required. During transport, animals need increased space to adopt postural changes to brace themselves while standing and to adjust their footing in response to acceleration. For long journeys, animals may need to lie down and sometimes to drink and feed onboard the vehicle. In this situation, extra space is required to provide access to troughs and drinkers so that the animals can attempt to eat or drink simultaneously. If insufficient space is provided, the animals can experience reduced stability, fatigue, bruising, and stress (Tarrant, 1990). If the vehicle is driven well on good quality roads, the animals benefit from plenty of space. Overcrowding must always be avoided, but in some situations where they are exposed to violent movement, there is some evidence that animals can benefit from mutual and lateral support to reduce their potential for movement and subsequent injury (Eldridge and Winfield, 1988; González et al., 2012). Increasing stocking density increases the number of animals in a container or vehicle and the amount of metabolic heat and moisture produced. Unless this extra metabolic heat and moisture can be effectively removed by
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ventilation, it can be detrimental at warmer temperatures and predispose to heat stress. Lowering stocking density reduces the risk of heat stress. At low temperatures, a high stocking that provides beneficial metabolic heat can reduce the risk of cold stress. In some situations, overcrowding can predispose to suffocation and sometimes it can obstruct ventilation openings.

Journey duration

Land transportation can last several hours or several days. Sea transportation can last several days or weeks and can include road journeys. Air transport may only last several hours but it also requires road journeys. The major concerns that have been expressed over the effects of long journeys on the welfare of animals are that animals are exposed to prolonged stress; excessive periods without feed and water; fatigue and lack of rest; an uncomfortable physical environment; and increased risk of injury, illness, or death (Transportation Code of Practice Scientific Committee, 2018). Some countries have regulations that restrict maximum journey duration (European Council, 2005). However, there is no consensus on specific maximum journey durations. A rationale for restricting specific journey durations can be made when it is clear that (a) aspects of welfare are adversely affected after a specific journey duration and thus stopping a journey before this occurs would help to minimise these adverse effects; (b) the animals are exposed to a continuous, aversive experience, and that restricting journey duration would minimise the duration of this experience; and (c) that the many risk factors associated with transportation that have the potential to adversely affect aspects of welfare cannot be mitigated by an improved journey quality, and the longer the journey, the greater the risk (Cockram, 2007). However, there is a strong argument that too much emphasis has been placed on journey duration, and greater focus should be placed on the quality of the journey. The quality of a journey will affect how the animals respond to a journey of long duration. If environmental conditions (including driving style, road conditions, vehicle design and operation, space allowance, thermal conditions, and ventilation), the fitness of the animals and the pre- and post-transport handling of the animals are optimal, it should be possible to transport certain types of animals over long distances without major welfare problems. If, however, there is widespread non-compliance with regulations or standards, together with inadequate enforcement or supervision, and optimal conditions are not provided, the argument for limiting journey durations is strengthened (Cockram, 2007).

Feed and water deprivation

Many farm animals are not provided with feed and water during a road journey. The period of feed and water deprivation is the sum of the journey duration without access to feed and water and the periods pre- and post-transport during which the animals are not given access to feed and/or water. On long journeys, some vehicles, especially in Europe, carry equipment and a quantity of appropriate feed and water to feed and water the animals during the journey. However, “rest” stops during long journeys need to be long enough for each animal to eat and drink. There is considerable debate over when journey duration should be limited by the physiological requirements of the animals for feed and water and to avoid severe hunger and thirst. Stopping a journey to unload the animals to provide a period of rest, feed, and water can increase the risk of stress, injury, and infectious disease.

Contingencies

Protocols and procedures are required to monitor and, when necessary, inspect the animals and essential equipment during a journey. For long sea journeys, a formal risk assessment and pro-
procedure for management of the risks is required (Stinson, 2008). A contingency plan is required to establish procedures for events such as delays, accidents, and compromised or unfit animals. Road accidents can occur due to the vehicle overturning, collisions, or mechanical failure. This can result in mortality, injury, or escape of animals onto the road (Miranda-de la Lama et al., 2011). During a journey, an efficient means of communication should be available, and navigation, tracking, and recording systems are valuable to provide a journey log and benchmarking to improve future journeys.

**Conclusions**

If the fitness of the animals and the quality of the journey conditions that they experience are optimal, farmed animals are likely to be stressed by the novelty of their environment, but they can be transported without suffering. However, there are numerous factors that can increase the risk of animals experiencing negative affective states as a consequence of transportation, and many welfare issues occur during routine transportation. The potential welfare issues associated with transport include stress, thermal and physical discomfort, pain, fatigue, sickness, hunger, and thirst. The quality of a journey is affected by factors such as vehicle design, stocking density, ventilation, the standard of driving and quality of the road, the journey duration, the environmental conditions, and the associated handling and management of the animals. The welfare issues are multifactorial, transport conditions are diverse and challenging, and different types of animals have distinct requirements. These issues are of such significance that they are regulated by detailed industry standards, codes of practice, and legislation.

**References**


Transportation


