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Pre-transport factors affecting the welfare of cattle during road transport for slaughter – a review

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Abstract

In terms of animal welfare, transport *per se* is very important in the course of the transportation process and transport duration is considered as one of the determining factors, however, the phase that precedes the actual transport is also of great importance (and often even more important) as to stress induction. This pre-transport phase includes many aspects, such as on-farm handling, rearing conditions, assembly of animals, classifying, weighing, repenning in a new environment, re-grouping, mixing with unfamiliar animals, and handling at loading, which is regarded as the most significant factor affecting animal welfare. Therefore, the present work focuses on the factors that play a role during this phase. Those factors are naturally interconnected and their adverse consecutive effects on animal welfare can hardly be separated.

Livestock, loading, transportation, stockpersons, stress

Cattle are transported by road, rail, sea and air for the purposes of breeding, exhibiting, fattening, and slaughter. Road is usually a better choice, offering a quicker and more convenient transportation, and stock is handled to a lesser degree (Tarrant 1990). In outline, the road transport of livestock includes the assembly and loading of animals at their place of origin, confinement on a moving or stationary vehicle, unloading, and finally lairage or penning at their final destination (Tarrant and Grandin 2000). It is obvious that the effect of road transport is a multi-factorial problem in which a combination of stressors rather than a single factor is responsible for animal well-being and meat quality after transport (Schwartzkopf-Genswein 2012).

Transportation thus constitutes a crucial risk factor in the pre-slaughter logistics chain in terms of a threat to animal welfare and the development of stress in animals. Stress factors related to transportation may adversely affect health, productivity/performance, and the market value of animals (Minka and Ayo 2007).

Regarding individual factors contributing to the induction of stress, those most explored and discussed are transport duration, loading density, vehicle design, and trailer microclimate, which are factors directly connected with the (usually long-term) transportation itself. These aspects have covered in a large number of studies, in which transport is defined as a stressful procedure which may endanger animal welfare (Tarrant 1990; Knowles 1995), has an unfavourable impact on meat quality (Maria 2003), and which even increases mortality among the transported animals (Earley et al. 2012). Nevertheless, various factors, the action of which can already be identified prior to the beginning of actual transport, may influence the development of stress and, subsequently, carcass and meat quality, as well. Some of them have an effect immediately before the beginning of actual transport (handling at loading, fasting), some act with a certain time

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advance (pre-transport nutrition, mixing with unfamiliar animals, season, and ambient temperature), and, finally, some have an effect a long time before actual transport takes place (form of housing, human-animal contact). Thus, pre-transport phase comprises, narrowly, all activities connected with the planned transportation (selection of animals, their classification, weighing, assembly, mixing of unfamiliar animals, etc.), extending over the whole period from the birth of animals (type of animal husbandry, rearing conditions, human-animal contact etc.) till the beginning of transport itself.

Fortunately, the majority of the abovementioned factors influencing animal welfare during the pre-transport phase can be affected by means of managerial measures and thus it is possible to reduce to a substantial extent their adverse effects on animal well-being and stress induction. Provided that the adverse effects of these pre-transport factors are reduced as much as possible, the probability that animal welfare during the transport phase itself will not be compromised increases. Therefore, the pre-transport preparation of animals plays an important, if not essential, role. For example, Broučeк et al. (2007) reported that animal welfare is affected by many stressors during the transport process, the most stressful being: handling at loading, repenning in a new environment, mixing with unfamiliar animals, fluctuations in ambient temperature, and lack of feed and water (fasting), all of which occur during the pre-transport phase.

In terms of the course of transport *per se*, there is a number of findings concerning factors affecting welfare of transported animals. Therefore, the goal of this review was to present available information on factors that might influence welfare of transported animals which appear even before the beginning of transport. We attempted to arrange and describe them clearly, find their mutual links and highlight potential hazards.

Route planning

Thorough route planning allows unpredictable situations that could arise in the course of transport to be handled efficiently. Route planning is a complex procedure. It is necessary to take into account all known factors which could affect the transportation and, above all, the welfare of the transported animals. The effectiveness of animal transport, which can involve animal collection from various locations or queuing and unloading at the slaughterhouse, can be greatly improved when supported by a dynamic and knowledgeable planning process that takes into account road conditions, weather, traffic conditions, transport time, and distance (Aradom 2012).

Obviously, it is not easy to harmonize all epizootological, economic, technical, personnel, and animal welfare requirements and satisfy all legal regulations dealing with the issue of animal transportation. Besides other factors, the following requirements pose a challenge for logistics management: 1) preventing heat stress by not transporting animals on especially hot days or during especially hot periods of the day; 2) reducing noise, vibration and sway during transport, which have the capacity to unsettle the animals and/or the potential to increase the number of slips and falls, by choosing well-maintained roads with a smooth surface that are as straight as possible; 3) reducing transport times by eliminating as much as possible queuing at the slaughterhouse; 4) keeping a balance between profitability on the one hand and the need to comply with all legal requirements and adequately remunerate personnel on the other; 5) avoiding traffic congestion and sections of roads where accidents often occur, and planning sufficient rest stops, which are absolutely necessary for the maintenance of good animal welfare.

In essence, the transport of live animals to slaughterhouses is a typical problem of logistics, which involves a finite number of vehicles with limited capacity that must collect animals from various locations and deliver them in a continuous flow to the slaughterhouse (Gribovskaia et al. 2006). A common vehicle routing problem involves determining

the routes of least-cost from a set of geographically scattered farms to a slaughterhouse or logistic centre (auction market, storage centre, or pre-export assembly depots). The individual routes must be designed in such a way that each point is visited only once by exactly one vehicle with all routes starting and ending at a destination point, so that the total demands of all points on one particular route will not exceed the capacity of the livestock vehicle (Bochtis and Sorensen 2009).

Furthermore, with respect to animal collection, there are two kinds of time windows and they occur for two different reasons. The first type occurs because the farmer is not always available to release his animals. This is why the farmer must be visited on certain days of the week or within certain time intervals during the day. The second type of time window is broader, typically two or three days in duration, and appears because the animals need to be slaughtered within a certain time interval in order to have the desired weight at slaughter (Oppen and Lokketangen 2008).

Additionally, as the number of slaughterhouses decreases, the demand for cost-effective transportation increases, as is the complexity of route planning. The fact that many slaughterhouses have become specialized in terms of animal types has the same impact (Ljungberg et al. 2007). Moreover, the ease of animal trade among countries, facilitated by international agreements (i.e. NAFTA and EU free-trade), and improvements in road networks and the technical characteristics of vehicles have led to a rise in international road transport (Dalmau et al. 2013). Production systems are more stratified due to specialization, creating subsystems or links that are sometimes widely spread in terms of geographical location. Consequently, the number of transport variables in these systems is increasing and the majority of animals raised in them will undergo more than one journey during their lifetime (Miranda-de la Lama et al. 2014). Poor logistical management - in particular, imperfect route planning - clearly results in higher morbidity, mortality, live weight losses, carcass bruising, and meat quality defects (Paranhos da Costa 2012). Therefore, in the process of route planning, one must take into consideration many aspects, in particular transport costs and relevant legislation, with an overall emphasis on animal welfare.

Finally, it is of great importance to make producers and transporters financially accountable for problems and losses resulting from the transportation process. Bruises on slaughter cattle were greatly reduced when producers or transporters had to pay for them (Grandin 1981). An understanding of how economic factors affect the way farm animals are treated will help policy makers to improve welfare. Holding people financially accountable for losses or providing incentives for low losses will greatly improve animal treatment (Appleby 2008).

Generally, the following recommendations should be taken into consideration. The goal should be to slaughter the animals as close to the farm as possible and provide a bonus to the farmer or driver for complying with that objective. Journey time should be short enough to avoid the requirement to unload the animals for resting. The net effect of unloading animals for rest periods could be an increase of the biological cost of the stress response. Good monitoring of the animals should be ensured with inspections of adequate frequency. Navigation systems should incorporate temperature monitoring and warning systems. Common minimum standards should be set up, in particular regarding the data type to be recorded, the system and the on-board architecture. Before a journey starts, there must be decisions about the stocking density of animals on the vehicle and the grouping and distribution of animals on the vehicle. Planning should also take account of temperature, humidity, weather conditions (shrink can be increased by bad storms, hot weather and long delays during the trip or while waiting for unloading) and the risks of disease transmission. Planning of routes should take account of the needs of the animals for rest, food and water. Drivers or other persons responsible should have plans for emergencies including a series of emergency telephone numbers (Broom 2008).

Animal-related factors

Animal-related factors play an immense role in animal transportation. From the logistics management viewpoint, animals should not be regarded as a homogenous mass. Not only is the species of transported animals of particular importance; within a given species, breed, temperament, age, category, size and condition are also of major significance. Cattle livestock can be divided into the following groups according to age and category: calf, feeder, fat, cull, and breeding stock. Furthermore, cattle can also be divided into groups according to size. In particular, when handling livestock, one must also consider differences in temperament among individual animals. Different attitudes should be applied for animals that are aggressive, active, timid, calm, etc. The category and size of animals directly influence the loading density and distribution of animals in the trailer. The age and category of animals affect the choice of appropriate feed, amount of water, number and duration of rest intervals, bedding, and slats. The breed and temperament of animals affect behaviour and thus mainly influence loading time and the total number of injuries sustained. Individual breeds can differ among themselves, e.g. in terms of horn presence, skin thickness, musculature, or behaviour. All these factors have an impact on the resulting quantity of transport-related bruising and other injuries in slaughtered animals.

Young animals are more vulnerable to transport and pre-slaughter stress than adult ones because their immune systems are naive and they have not yet experienced exposure to a new environment (Swanson and Morrow-Tesch 2001). Recently weaned calves are more likely to succumb to bovine respiratory disease, or BRD (a complex of diseases caused by *Pasteurella* species, the bovine respiratory syncytial virus, the infectious bovine rhinotracheitis virus, and parainfluenza virus 3) (Barnes et al. 1975); therefore, they should not be transported if less than 4 weeks old (Knowles 1995). One possible way of preventing morbidity and mortality caused by the bovine respiratory disease complex is to precondition animals before transport. Applied preconditioning programs include weaning and holding at the place of origin for a period of time (15–60 days), a vaccination program, deworming, castration of intact male calves, dehorning, training calves to eat from a bunk, and beginning the transition from a forage-based diet to a grain-based diet (Duff and Galyean 2007). The main beneficial effect of preconditioning is the separation of stressors such as castration, dehorning, weaning, vaccination, transport, and marketing over time (Cole 1985). Sub-clinical viral infections may make adult animals more susceptible to secondary bacterial infections that can lead to animal death during or after transport (Brogden et al. 1998).

It is well documented that transportation is more likely to affect adversely the welfare of a calf than a mature animal (older than 17–19 months), because of the incomplete development of the calf's hypothalamic-pituitary axis (Eicher et al. 2006) and because of the fact that calves are exposed to a multitude of novel and stressful events, including weaning, processing, handling etc. around the time they are transported (Grandin 2001). This is also manifested by the increased incidence of morbidity and mortality once they arrive at the feedlot (Fike and Spire 2006). The same conclusions apply to old or cull animals and the potential for welfare and carcass quality issues to arise with respect to this category of animals is high because of their low economic value (Grandin 2001). According to Schwartzkopf-Genswein et al. (2012), the effects of transportation vary greatly depending on the type (age, size, condition) of the animal being transported. For example, mature or fat cattle (> 500 kg) transported more than 400 km for slaughter had few quantifiable welfare issues (shrinkage, death, lameness, becoming non-ambulatory) in comparison with calves, feeders, and culls (González et al. 2012). In the same study, cull cattle were found to be at greatest risk of poor welfare during long-term transportation because they had the greatest probability of becoming lame at the time of loading and

unloading and being declared non-ambulatory or dead at the end of the journey compared to calves and feeders (González et al. 2012). It was suggested that fat cattle are in better condition (i.e., they have higher body condition score) and have a more potent immune system, which results in better health compared to calves and feeders (González et al. 2012).

Nicholson et al. (2013) recorded that beef cattle had higher numerical percentages of no defects present (72.0%) compared to dairy cattle (63.0%) when evaluated for a variety of reproductive, health, and management conditions (e.g., bovine ocular neoplasia, knots, lameness, mad/manure location, prolapse (rectal and vaginal), retained placenta, latent and insect hide damage, lumpy jaw (actinomycosis), extreme emaciation, foot abnormalities, broken penis, udder problems, and abscesses). Cattle prods were used to a greater extent on beef cattle loads (32.4%) compared to dairy loads (15.4%); also, beef cattle loads were more likely to have a variety of driving aids used more aggressively on them. This fact may seem a bit surprising when we take into consideration that dairy cows were more frequently lame (48.7%) than beef cows (16.3%). According to Hartung et al. (2003), bulls, steers and heifers react differently to transport and, thus, transport schemes should be adapted to the various needs of animals. Death losses in fattened cattle connected with their transport for slaughter in the Czech Republic were 0.007% in the period from 1997 to 2004 (Malena et al. 2006) whereas the mortality rate of dairy cows transported for slaughter was 0.038% (Večerek et al. 2006a) and the calf mortality rate was 0.026% (Večerek et al. 2006b). In the period from 1997 to 2006, Malena et al. (2007) reported the following mortality rates for individual categories: excluded dairy cows 0.0396%, calves 0.0269%, and fattened cattle 0.0069%. In a recent study, Šímová et al. (2016) found the greatest mortality in calves (0.296%), followed by excluded dairy cows (0.207%) and feeders (0.058%), and the lowest mortality in fattened cattle (0.017%).

Handling during pre-transport (i.e., the collection of animals, weighing, loading), the transportation itself, and post-transport handling (i.e., lairage time) had different impacts on the coping strategies of the different categories of cattle. During transport, loss of body weight in steers coming from pasture (−6.65%) was found to be higher compared to bulls (−4.60%), but their recovery (in body weight) was better during lairage time. All categories of cattle exhibited a catabolic energy metabolism during transport, but only in bulls and, to a further extent, in heifers did it result in the tendency to exhibit a ketotic metabolism during the second phase of transport and lairage time (Marahrens et al. 2003).

Behaviour and mean loading time per animal differ significantly among individual breeds of cattle under the same transport conditions. Correlation analysis conducted by Minka and Ayo (2007) showed that the level of behavioural activity and length of loading time were positively and significantly correlated with the number of injuries. A temperamental nature, in the case of African Red Bororo cattle breed characterized by aggressive behaviour, loose and thin skin, and the presence of horns were the major causes of injuries to cattle. The authors demonstrated breed differences with respect to injuries sustained during transportation.

Cattle have been bred for particular breed characteristics for hundreds of years. As a consequence, there may be differences between breeds in how they react to particular management conditions. Farm animal selection for breeding has been directed especially toward maximizing productivity. In some farm species, there are consequences of such selection for welfare during handling and transport (Broom 1999). Some beef cattle that have grown fast have joint disorders, which result in pain during transport and some strains of high-yielding dairy cows are much more likely to have foot disorders. Modern strains of dairy cows, in particular, need much better conditions during transport and much shorter journeys if their welfare is not to be poorer, than the more traditional breeds of dairy cow used 30 years ago (Broom 2008).

With respect to animal condition, apart from some exceptions, only healthy animals can be legally transported. The selection of animals fit for transportation (i.e., animals in good health condition) is essential for successful transport since misconduct in animal selection may increase morbidity, or even mortality among animals, which is not only inconsistent with animal welfare requirements, but also leads to considerable economic loss. Broom (2003) emphasized animal health as a factor in animal welfare. According to Večerek et al. (2006b), animal health is one of the main factors affecting animal welfare, as diseases in animals decrease the level of their welfare during transport. Indeed, diseases may adversely influence the mortality rate during transport. From the viewpoint of animal categories, this issue is of particular importance in calves. The total number of calf deaths during transport for slaughter significantly increased owing to calf diseases. The mortality rate associated with transport for emergency slaughter was considerably higher. In general, good physical condition of animals is very important especially in the case of long journeys since animals spend long periods of time standing and trying to maintain their balance (Gebresenbet et al. 2011).

Animals least fit for transport are affected by the greatest losses in terms of welfare and meat quality, while market-ready animals in good condition appear to have fewer issues. Fat cattle are at lower risk of experiencing diminished welfare than feeders, calves or cull animals due to their robust condition (Schwartzkopf-Genswein et al. 2012).

Sometimes transportation and handling studies appear to arrive at conflicting results and conclusions. This may be a result of differing degrees of fear, which is a very strong stressor; in most animals, psychological stress is actually stress from fear. Both previous experience and genetic factors influencing temperament will interact in complex ways to determine how fearful an animal may become when it is handled (Grandin 1997). A tame hand-reared animal may show little or no fear during handling but an extensively-reared animal with little human contact may exhibit a much stronger fear response. Animals having an excitable nervous temperament and a more reactive nervous system will probably experience greater amounts of fear when they are suddenly subjected to a new experience than animals with a calm, placid temperament (Grandin 1997).

The final animal-related factor influencing animal welfare during transport is a purely financial one: the greater the financial value of the cattle being transported, the greater the attention which is paid to their welfare.

In conclusion, the first stage of transport is the selection of animals to travel. Inspection should be made of these animals to check that they are fit to travel. Animals are prepared for the journey and this preparation will depend on the category and length of the journey envisaged. For shorter journeys, preparation can include movement away from the main herd to protect its health status (Broom 2008). Increased attention needs to be paid to the most vulnerable cattle categories. Attention needs to be paid to cull cattle despite their low economic value. Weaning is one of the most stressful times in a calf's life; pre-conditioned calves will shrink less.

Rearing conditions

Rearing conditions, in particular the existing form of housing, have a significant impact on the stress response of animals during their repenning in a new environment, re-grouping, mixing with unfamiliar animals, and handling at loading. Terlouw et al. (2008) claimed that the exact causes of stress depend on the characteristics and circumstances of each species, including the rearing system.

Separately-reared animals will react to transport-induced stress in different ways than animals reared in social groups. In addition, the system of husbandry applied at the farm of origin affects to a large extent the future reaction of animals to transport-related stress. Extensively-reared animals are generally more resistant and used to facing environmental challenges that are often unfavourable (Minka and Ayo 2007).

It was demonstrated that previous experience significantly determines an animal's perception of and reaction to emotional stress-inducing situations. After 30 min of rotation, driving and stopping, individually-reared animals without previous visual or social contact with other animals exhibited significantly higher concentrations of stress hormones compared to animals reared in social groups (Brouček et al. 2007). Moreover, animals reared in isolation occupy, after mixing, lower positions within the social hierarchy compared to animals reared in groups. High level of stress (due to lack of exercise and absence of social stimulation) and its behavioural and physiological consequences are the reasons why individually-housed animals also showed difficulties in walking and increased body temperature after transport (Brouček et al. 2007).

Steinhardt and Thielscher (2000, 2003, 2005a) investigated the reactions of dairy calves exposed to transport stress, namely from the viewpoints of rearing conditions, husbandry systems, and different breeds. They monitored physiological and biochemical indicators of stress in calves reared in groups of both constant and changing composition and also in calves reared in a single box. Their experiments demonstrated the strong impact of previous rearing conditions on the reaction of animals to transport-induced stress. They also confirmed the high individual specificity of the stress reaction to transportation. Grandin (1997) documented that cattle habituated to a squeeze chute may have baseline cortisol concentrations and be calm in behaviour, whereas extensively reared animals may have elevated cortisol concentrations in the same squeeze chute. While the squeeze chute is perceived as neutral and non-threatening by one animal, the novelty of it may trigger intense fear in another. Novelty is a strong stressor when an animal is suddenly confronted with it. Regardless of treatment, intensively-reared calves appeared markedly less fearful of handlers during approach tests compared to extensively-reared calves, which made evident attempts to escape from the test facilities (Croney et al. 2000).

In contrast, the rearing of cattle under the traditional extensive management system results in animals that are hardy and well adapted to stressful environmental conditions, including draught activity over the years (Minka and Ayo 2007). Moreover, outdoor farming has a more favourable welfare image largely because of the freedom the animals enjoy to exhibit a wide range of species-specific behaviour and possibly because of the perception that such farming involves less stress and fewer health problems (Hemsworth 1995).

The existing form of housing is also relevant in terms of heat stress. The amount of heat generated by cattle is influenced by the type of housing in which they are kept. Animals which were grazing prior to transportation produce less heat compared to animals housed in closed spaces. On average, animals increase their body temperature inside the vehicle by 3 °C relative to the ambient environment (Appleby et al. 2008).

In conclusion, when animals are kept in a way that makes them very vulnerable to injury when handled and transported, this must be taken into account when transporting them, or the rearing conditions must be changed (Trunkfield et al. 1991).

Human-animal contact on the farm

When transporting animals, it is not possible to prevent their close contact with unknown people, which can induce considerable emotional stress in animals. The intensity of such a stress response depends partly on the innate temperament of individual animals and partly on their previous experience with human contact. In this general context, the following activities can be considered critical points: the process of animal selection, the weighing of animals, gathering in assembly pens, and loading onto the vehicle. From the transport management perspective, it is extremely difficult to influence this factor, since relationships between animals and humans are formed at the farm of origin long before the

transport itself begins.

Lensink et al. (2000) investigated the influence of gentle touching by stockpersons on the welfare of calves. It had been demonstrated previously that regular stroking and allowing calves to suck fingers resulted in less avoidance and more forthcoming behaviour toward people. Calves that received gentle contacts were less agitated and tended to defecate less when handled in a cart on wheels compared to the control calves, but no significant differences were found in responses to novelty or surprise stimuli, responses to ACTH, or catecholamine synthetic potential. It was concluded that the provision of gentle contacts in veal calves reduced their adverse reactions to handling. Such contacts reduced the response to transport-related stress, indicated by differences in the glycolytic potential. Moreover, these reduced reactions to handling and the decreased incidence of abomasal lesions (due to lower stress level) improved the calves' welfare during transport (Lensink et al. 2000).

Lensink et al. (2001a,b) also found that it took less effort to load calves that had received additional contact with humans. As for the impact of farmers' behaviour on calves' reactions to transport, Lensink et al. (2001a) concluded that calves with regular positive contacts were less fearful of people, which improved handling. Steinhardt (2003), who studied the influence of intensified human-animal contact on the responses of animals exposed to the transport process, reported that changes in heart rate and plasma cortisol indicated the relevance of acclimatisation of animals to handling. When young cattle have been handled for a short period just after weaning they are much less disturbed by the procedures associated with handling and transport (Le Neindre et al. 1996).

In conclusion, human contact prior to handling and transport is essential. There should be repeated humane handling during rearing and immediately prior to transport, in order to minimise aversive reactions (Broom 2008).

Pre-transport nutrition

The issue of pre-transport nutrition and fasting is closely connected with the expected duration of transport. Animals must be carefully prepared for the transportation in reference to energy and fluid balance (Marahrens et al. 2003). Fasting and pre-transport nutrition is also of great importance from the viewpoint of heat stress. In cattle, the greatest amount of heat is produced by the rumen because of its exothermic fermentation processes during feed digestion. This process culminates approximately 4–6 h after feeding (Dewell 2010). Therefore, it is recommended to transport only fasted animals. Moreover, pre-transport fasting may prevent transport sickness, as well as spillage of gut contents and contamination of meat at the slaughterhouse.

It was demonstrated that cattle lose 6 to 10% of their body weight on average during transportation. The amount of weight loss is mostly influenced by transport duration, but is also partly caused by dehydration. In general, the resultant weight loss is partly accounted for by the depletion of fat reserves, partly by the loss of bodily fluids (Fike and Spire 2014). To reduce weight losses to a minimum, it is necessary to minimize transport duration as much as possible and provide animals with a sufficient quantity of water. However, it is difficult to provide water continuously and many animals will not drink during vehicle movement, so frequent stops of sufficient duration for drinking may be necessary (Appleby et al. 2008). Moreover, drinking devices pose a novelty, which is a strong stressor. This is especially true when an animal is suddenly confronted with it. In the wild, novelty and strange sights or sounds are often a sign of danger (Grandin 1993).

Body weight loss not only affects the carcass weight of slaughtered animals, which has a direct impact on market price, but also correlates positively with the incidence of bovine respiratory disease (Fike and Spire 2014).

According to Schaefer et al. (2001), the importance of pre-transport nutrition and

its role in reducing meat quality aberrations on long journeys should not be overlooked. Although fasting is not a direct cause of dark-cutting in beef, it lowers muscle glycogen reserves, thus rendering animals more susceptible to dark-cutting from additional sources of stress. Fasting also inhibits muscle glycogen resynthesis during post-stress recovery (Tarrant 1990). Todd et al. (2000) suggest that with correct feeding regimes and transport protocols, welfare problems in young healthy calves being transported for up to 12 h can be minimised provided they are slaughtered within 30 h of the start of transportation. Schaefer et al. (1997) found that the application of oral electrolyte therapy, especially if similar in its constituents to interstitial fluid, seems to reduce the physiological changes related to transport and handling stress. Resulting improvements in both live and carcass weights (less shrinkage) of up to several percent in treated animals as well as a reduction in meat quality degradation (reduced dark cutting) were obvious in such trials. These studies suggest that the use of electrolyte therapy might be an effective method to reduce stress in transported cattle.

For longer journeys, where watering and feeding will be necessary on the vehicle, it can be an advantage to collect the animals involved 2–3 days before the transport, so that they can be prepared for the journey and become accustomed to the feed that will be offered en route (Broom 2008).

Mixing with unfamiliar animals

Mixing of unacquainted animals is a common practice in transport and lairage, both to homogenize the weight of the animals and to increase profit. This may lead to stressed and injured animals, a combination that facilitates infections and decreases welfare (Appleby 2008).

When performing operations such as mixing cattle with unfamiliar animals or re-grouping or repenning them in a new environment, which play an important role within the pre-transport phase, one must take account of particular features of cattle as an animal species, particularly their demands with respect to private zones and social hierarchy. Cattle need a certain private zone around themselves to provide a feeling of safety. In cattle, this distance ranges from 150 to 750 cm, but it can be much larger (Moran 2002), usually in individuals not accommodated to frequent manipulation or the presence of humans. Within a cattle herd, a relatively stable hierarchy is established and maintained (Stricklin and Gonyou 1981). Conflicts occur rarely, mainly in cases when an individual struggles to move to a higher social position within the established hierarchy. When it is necessary to change the composition of a herd and integrate new animals prior to transport, it is advisable to exchange more individuals. The newly-created group should be then driven to a different place so that all the animals find themselves in a new environment. These measures ensure that a new hierarchy in the herd is established gradually without animals being exposed to excessive stress. Cattle have a very good memory which enables them to remember the hierarchical positions of between 50 and 70 animals. They remember the positions of individual animals even when the herd finds itself in a new environment (Fraser and Broom 1997).

Social re-grouping may occur at any point in the transport chain (Tarrant 1990). Von Holleben et al. (2003) included it among the stress factors affecting animal welfare. Mixing groups of unfamiliar animals leads to an increase in the number of social interactions, which may result in psychological stress and physical exhaustion. For cattle in general, disruption of the social group, novelty of the situation and, for calves, mixing with unfamiliar animals are known stress factors (Miranda-de la Lama 2014).

The age, category, and sex of animals, as well as their breed and temperament, can influence their aggression and their sexual and exploratory behaviour. The frequency of social interactions

(aggressive behaviours: butts, pushes, threats and mock fights; sexual behaviours: mounting and chin-resting) is higher during the pre-transport phase (assembly, repenning in a new environment, loading) compared to the transport phase *per se* (Tarrant 1990). This pattern was found both in non-mixed and socially regrouped animals. Higher frequencies of social interactions were reflected in corresponding increases in the activity of the muscle enzyme creatine kinase, which is released from muscle into the blood stream during vigorous or unaccustomed exercise, or as a result of physical damage to the musculature such as bruising (Tarrant 1990). Mounting activity is the behaviour most closely associated with muscle glycogen depletion and dark-cutting in beef. This behaviour is stimulated by social re-grouping and also by the oestrus in groups of females. In contrast, the frequency of exploratory behaviour and urination increased as the complexity of the transport process increased, the latter probably indicating a growing fear. The stress and disturbance gradually increased in the following order: during repenning < during stationary confinement < during confinement in a moving vehicle. Also, plasma cortisol concentrations increased, social interactions were suppressed, and urination increased (Tarrant 1990). Competitive interactions are most expressive in male feeders. When bulls are regrouped and exposed to a new environment, their sexual activity (jumping, mounting), mock fighting, including offensive and defensive movements; and exploratory behaviour increase significantly. Naturally, therefore, the production of stress hormones and heart rates also increase (Brouček et al. 2007). Through transportation, the animal is always moved to a novel environment, which presents emotional stress. Moreover, the fear of humans compounds the situation. Even minimal contact with unknown humans induces significant stress in animals, accompanied by increased aggression and the production of stress hormones (Brouček et al. 2007). It must be emphasized again that previous experience with humans and manipulation plays an important role in the responses of animals to these pre-transport operations.

In relation to the transport practices it is recommended that wherever possible, animals should be kept in stable social groups. Therefore, avoid mixing, if possible.

Handling at loading

Some studies indicate that the stress cattle experience during the transportation process is the consequence of poor quality handling at loading and unloading rather than the transport itself (Cole et al. 1988).

The issue of the loading procedure includes several aspects. The quality of handling and the experience of the handler are discussed below (see Stockpersons); other aspects influencing handling at loading include the following: the temperament of the animal (see Animal-related factors); the condition of the animal (see Animal-related factors); the use and quality of the handling facilities and tools; farm configuration; group size; presence of strange sights, sounds and other distractions; and delays in loading. Many authors (e.g. Grandin 1999; Wikner et al. 2003) consider handling at loading to be the most important factor with respect to the induction of transport stress. Warris et al. (1995) reported that cortisol concentrations increased owing to the stresses associated with loading and the first part of the journey, but then recovered as the journey continued. Nevertheless, with increasing transport duration, stress of transported animals rises again which is, however, rarely connected with time itself. It is other factors associated with transport, that may result in poor welfare with time. Among them, the condition of the animal prior to transport or in connection with handling and loading has been identified as one of the most important.

Grandin (1999) focused on the reduction of stress levels in cattle by the introduction of low-stress cattle-handling techniques (e.g., the Behavioral Principles of Restraint: blocking vision, slow steady movements of the restraint apparatus, optimum pressure, and providing secure footing; Handler Movement Patterns; Slow is Faster etc.). To improve and facilitate cattle-handling, it is further recommended to move small bunches of cattle, avoid isolating

individual animals, eliminate electric prods and visual distractions, reduce noise (Grandin 1998). According to Tarrant (1990), loading difficulties are often caused by overloading, with the last few cattle being driven forcefully on board.

Obviously, science supports the notion that good quality handling reduces stress. While it is logical that good handling results in better welfare (fewer indicators of stress, injury and death) and carcass and meat quality (less bruising and dark cutting), information on these relationships as they relate to transport is lacking in the scientific literature. This is likely because of the difficulty in separating the effects of handling from transport because animals cannot be transported without handling (Schwartzkopf-Genswein et al. 2012). As well as sampling is – most likely for practical reasons – carried out before loading and after unloading. This confounds the effects of handling in connection with transport, and also does not allow assessment during the actual journey (Nielsen et al. 2010). Nevertheless, there are some studies comparing animals that were transported with animals that were left behind to act as controls (Nyberg et al. 1988; Knowles et al. 1995).

Fire and Spike (2006) concluded that even small improvements in handling connected with the transportation of calves would reduce the degree of stress and incidence of bovine respiratory disease. Maria et al. (2004) demonstrated that trouble-free loading resulted in lower levels of stress. In general, the more efficient and smooth the loading process performed by a haulier, the lower the levels of stress experienced by the transported animals. This factor is particularly important with respect to routes covering many farms, feedlots, or loading stops (Miranda-de la Lama 2014).

When considering the most demanding phase of pre-transport, some particularities of cattle concerning their perception, behaviour, and social hierarchy play a crucial role during handling at loading. They are especially reflected in the behaviour (aggressive behaviour, sexual behaviour, exploratory behaviour) of animals and have a direct impact on the loading time and injuries sustained during loading. Minka and Ayo (2007) demonstrated that cattle that exhibit higher levels of behavioural activity and experience longer loading times had higher numbers of injuries. The level of behavioural activity and length of loading time are thus suitable indicators of animal welfare during transportation: the higher the level of behavioural activity, the higher the incidence of injuries. Naturally, high scores for behavioural events are positively correlated with some objective physiological indicators of stress such as plasma concentrations of cortisol, glucose and lactate, the activity of creatine kinase and the pH of the meat (Maria et al. 2004). The quantity of behavioural activities can be influenced by the management of the animals, the respective breed, and the purpose of production (Minka and Ayo 2007).

With regard to loading facilities, they should be properly maintained. Concrete or metal ramps should be used, preferably including opaque sideboards to prevent the cattle becoming distracted during loading (Maria et al. 2004). Villarroel et al. (2001) collected data on methods and facilities for loading cattle transported to slaughter in Spain. Loading facilities were adequate and loading times usually short, but some farms continued to use cattle prods and weather-proofing was generally poor. As far as vehicles are concerned, in many competitive logistic chains in various countries, some vehicles are equipped with well-designed ramps while others have hydraulic lifts on tailgates. Livestock trucks often have an integrated loading/unloading device, where the ramp angle should not be steeper than 20 degrees, i.e., 36.4% to the horizontal for calves and 26°34’ or 50% to the horizontal for cattle other than calves (Miranda-de la Lama 2014). The maximum recommended angle for adjustable ramps for cattle is 25°. Ramps should have a level dock at the top equal to one animal body length. Nonslip flooring is necessary, since it is impossible to handle large animals safely when they are slipping on the floor or panicked because they are losing their footing. Animals will balk at sudden changes in floor texture or colour, therefore flooring surfaces should be uniform in appearance and free from

puddles (Lynch and Alexander 1973). Drains should be located outside the areas where animals walk. Flooring should not move or jiggle when animals walk on it. Stairsteps are recommended on concrete ramps. Stairsteps are easier to walk on after the ramp becomes worn or dirty. Recommended dimensions are a minimum of 30 cm tread width and a 10 cm rise for cattle. The steps should be grooved to provide a non-slip surface. When cleats are used, they should be spaced 20 cm apart for large cattle (Mayes 1978). On outdoor ramps that become covered with ice, closely spaced cleats may be more likely to become slick. Both loading and unloading ramps should have solid fences (wild animals tend to be calmer in facilities with solid sides). The crowd pen that leads to the ramp should also have solid sides and it must never be placed on a ramp. Crowd pens must be level. Single file, curved ramps with solid fences are very efficient for loading cattle onto trucks. The floor appears more solid when the animals walk across the slats. To facilitate animal movement, the animals must not be able to see light or reflections off water under the slats (Grandin 1990).

In general, it is a fact that even simple improvements can make a significant diference to animal welfare, such as building well-designed ramps for loading and unloading and training people in animal behaviour and low stress handling methods (Grandin 2008).

Loading (and unloading) delay is a further factor that may add stress to the transportation process. However, González et al. (2012) concluded that there were no discernible effects of loading delay on cattle condition based on visual evaluation (e.g. presence of injuries, difficulties in walking) given that the time taken to load cattle was 20 and 30 min on average, with a maximum of 5 and 3 h (such loading time is extremely long, signalizing presence of problems), respectively.

In conclusion, quiet handling methods should be used for moving cattle, and handling facilities should be well-designed. Cattle should not be yelled or whistled at. The use of electric prods, canes, whips and dogs should be avoided. If not all animals are to be sold, then cattle should be sorted 1–2 weeks before weighing and selling. Even illumination and gently curved races without sharp corners facilitate the movement of the animals. Noise should be reduced and distractions removed. Non-slip flooring and good drainage to prevent pooling of water are also important (Grandin 2000). Cattle can be readily moved from place to place by human movements that take advantage of the animal's flight zone (Grandin 2000). Thorough knowledge of animal behaviour is important for good welfare during handling and loading (Appleby et al. 2008). Objective methods need to be used for assessing losses. Vague guidelines using terms such as adequate space or proper handling are impossible to implement because one person's interpretation of proper handling will be different from somebody else's. Loading of trucks should be measured with numerical scoring of variables such as the percentage of animals that fall, percentage that are electric prodded and the percentage that move faster than a trot (Grandin 2000; Maria et al. 2004). Familiar staff may reduce stress in animals during loading provided that the staff are well trained and have a positive attitude to animal welfare.

Stockpersons

A good handler of animals must meet many requirements. With respect to theory, they must have some knowledge of animal physiology and behaviour, animal welfare, and proper handling techniques. As for practice, the necessary requirements for good handling are a certain minimum level of ability on the part of the handler, a certain minimum level of experience, and a suitable attitude, all of which should be supported by appropriate incentives. Both theory and practice can be further improved by regular training. Trained staff employ better handling techniques and thus the intensity of transport-related stress and the number of injuries in handled animals is reduced. According to Villarroel et al. (2001), the welfare of cattle depends greatly on the attitudes and training of stockpersons and on the availability of appropriate facilities.

A bad attitude threatens efficiency, since negative behaviours (attributed to frustration, fatigue, and stress) are connected with impaired handling. People may hit animals and cause substantial pain and injury because they are trying to do the work very quickly, or because they do not consider the animals as subject to pain and stress, or because of lack of knowledge about animals and their welfare. Training staff can substantially alter their attitudes to, and treatment of, animals (Broom 2008).

Of course, these factors can increase the likelihood of injuries both in animals and stockpersons. It is usually an advantage for a handler to have significant previous experience; however, a handler's experience may sometimes be a disadvantage if it is based on mistaken or misused handling techniques, and/or if the handler lacks knowledge of new concepts regarding animal welfare and behaviour. A combination of experience and good health on the part of the handler seems to be not only ideal but also necessary. Hiring handlers with adequate training and positive attitudes towards animal welfare can have a beneficial effect both on the logistics chain and product quality (Peeters et al. 2008; Miranda-de la Lama et al. 2010).

The meat industry and the authorities in charge of enforcing legislation should inform personnel involved in the transport chain that improvements can be made by investing in training and by improving the design of facilities to reduce the substantial losses incurred from bruising and the impropriate use of sticks (Appleby et al. 2008).

Finally, a payment system should be implemented in terms of transport quality. That payment should be directly related to welfare; and criteria such as bruising score and meat pH should also be considered in that payment system. It is important to improve training and education on methods of animal handling. The training programmes should be supervised by competent authorities and must be a practical learning process. Drivers, farmers and slaughter associations should participate in these training programmes. In conclusion, handling improves when employees receive training, better supervision and higher payment (Appleby et al. 2008).

Conclusion

The issue of livestock transportation is becoming even more complex with the dynamically changing and increasing demands of modern consumer society. Legislation based on scientific evidence must be employed to improve animal welfare in the sphere of logistics. Animal welfare requirements must be strictly observed and supervised. Furthermore, it is necessary to convince consumers and the meat industry that products with a high ethical value have a growing economic importance and thereby present a business oportunity (Miranda-de la Lama 2013). Achieving optimum animal well-being and optimum carcass and meat quality will depend significantly on the quality of the animal transportation process (Passantino 2006; Schwartzkopf-Genswein et al. 2012). Improved pre-slaughter processes may positively affect animal cost, animal product quality, and consumer satisfaction (Ferguson and Warner 2008; Miranda-de la Lama et al. 2010).

In general, the fundamental preconditions for high-quality animal transportation are as follows: detailed science-based legislation, adequate investment (e.g. training of handlers, improved equipment), skilled personnel and adequate pay structures (qualifications, incentives, bonus systems), good on-farm handling and rearing conditions, an informed public (resulting in pressure to maximize animal welfare and product quality), and, finally, proper logistics management.

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