Livestock transport from the perspective of the pre-slaughter logistic chain: a review

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Abstract

New developments in livestock transport within the pre-slaughter chain are discussed in terms of three logistic nodes: origin, stopovers and slaughterhouse. Factors as transport cost, haulier, truck specifications, micro-environment conditions, loading density, route planning, vehicle accidents and journey length are discussed as well as causes of morbidity, mortality, live weight and carcass damage. Taking into account current trends to- wards increased transport times. Logistics stop over sand mixed transport, there is a need to develop systems of evaluation and decision-making that provide tool sand protocols that can minimize the biological cost to animals, which may have been under estimated in the past.

Introduction

Over the past few decades, food safety has become more of an issue in animal production systems, forcing governments and industry tore act to maintain consumer confidence. The concept of quality in the food sector has become more important for all involved in the agrifood chain (Sepúlveda, Maza & Mantecón, 2008). For consumers, quality goes beyond safety, or organoleptic and nutritional qualities, to include aspects related with production conditions and environmental impact (Becker, 2000). Animal welfare has become asocial concern, an attribute within a wide concept of meat quality (Maria, 2006; Schnettler, Vidal, Silva, Vallejos & Sepúlveda, 2007).

Farmers, hauliers, retailers and other meat chain participants increasingly recognize that consumer concerns for good animal welfare represent a business opportunity that could be profitably incorporated into their commercial strategies (Velarde & Dalmau, 2012). In this context, the meat industry and retailers are exploring the application of welfare friendly farm husbandry systems , management practices and breeding strategies, the implementation of monitoring, quality assurance during transport and pre-slaughter operations, certification schemes, and the dissemination of associated information to the consumer (e.g. Certified Humane from HFAC -USA ; Freedom Food from RSPCA-UK; Animal Welfare Certification System from AMIC-Australia)(Miranda -de la Lama, Sepúlveda, Villarroel & María,2013).

Livestock transports an essential component of the meat industry (Ljungberg, Gebresenbet & Aradom, 2007). Conventionally, animals are sent to the slaughter plant by the farmer through some intermediaries (with the participation of hauliers, whole salers and sale-yards). The main links of the chain are thus the farm, transport and slaughter plant. Recently, production systems have become more stratified including more intermediate steps between the main links, making national meat markets and associated pre-slaughter operations more dynamic and complex (i.e. auction markets, storage centres, classification of logistics centres, health checkpoints, key stop overs and resting points; Miranda- de la Lama, Rivero , et al., 2010). These developments can improve efficiency but also increase the incidence of pre-slaughter stress, leading to poor animal welfare (Ferguson & Warner, 2008). The efficient administration of a pre-slaughter logistic chain based on animal welfare will have a positive impact on the income of producers, distributors and retailers, because pre-slaughter processes may affect animal cost, product quality and consumer satisfaction (Ferguson & Warner, 2008; Miranda -de la Lama, Rivero, et al., 2010). Here we review current knowledge about livestock transport from the perspective of the pre-slaughter logistic chain using examples and requirements, to give the reader an overall view, with emphasis on animal welfare.

Logistics applied to pre-slaughter logistic chain

Logistic is the process of planning, implementing and controlling the efficient, effective flow and storage of raw materials, in-process inventory, finished goods, services, and related information from point of origin to point of consumption (including inbound, outbound, internal, and external movements) for the purpose of conforming to customer requirements (Christopher, 1998; Ginters, Cirulis, & Blums, 2013). The food supply chain is composed of companies that manufacture and process/transform raw materials and semi-finished products coming from primary activities such as agriculture, forestry, fishing and livestock (Manzini & Accorsi, 2012). The livestock move from feedlots /farms to processors who transform them in to meat products and organise delivery into the hands of end customers. This supply chain includes: breeders, farmers, stockers/backgrounders, feed lot operators, packers, processors, food-service providers and retailers. The pre-slaughter logistic chain is part of the meat supply chain that schedules, implements and controls the flow of a given animal from the point of origin to slaughter, to obtain homogenous, quality products in a competitive market that satisfy the require ments of the final consumer (Bosona&Gebresenbet,2013).

The key element in a pre-slaughter logistics chain is the transportation system, which joins the independent activities. Transportation is required throughout production, from the farm to delivery to consumers. Maximizing the coordination between each component will help to maximize bene fits. Modelling livestock transport logistics, particularly between farm /feed lot, intermediate stopovers and the slaughterhouse presents several challenges (Edge & Barnett, 2009). These include the substantial within - and between -year differences in the number of animals movements, loss in live weight and body condition during transit, the unpredictable impact of inherently variable climates on livestock supply and the ability of the transport system to move them correctly (Higgins et al., 2013). According to Bosona and Gebresenbet (2011) and Miranda-de la Lama (2013), the integration of logistic activities in livestock transport systems has the following palpable advantages: (1) to coordinate the transport of animals and reduce transport distance and time using optimized routes; (2) to pro-mote animal welfare; (3)to expand the market area for producers; (4) to reduce operational costs and increase competitiveness; (5) to reduce carbon dioxide(CO_2) emissions; (6) to improve trace ability of meat origin for authorities and consumers; (7) to strengthen the partnership between producers, distributors, retailers and consumers and (8)to encourage exchange of knowledge, experience and information.

Logistic nodes

Logistic management implies controlling several critical stages that include hauliers and intermediate points. The coordination of all of those operations is a complex undertaking that requires communication, synchrony and the efficient use of available sources by all concerned, in terms of time and frequency of delivery with the minimum cost and guaranteeing product quality (Ljungberg et al., 2007). In the generic meat logistics chain, farms, feedlots and logistics centres in specific production regions are responsible for moving livestock to slaughter houses. Slaughterhouses can be supplied by more than one production region (Soysal, Bloemhof-Ruwaard & Vandel Vorst, 2014). In this context, the nodes of a distribution network of the pre-slaughter chain can now be described as origin, intermediate and destination.

Origin node: farm or feedlot

The origin node is the beginning of the pre-slaughter logistic chain, normally the farm or feed lot, although there is an increasing verticalization in supply chain management in almost all species (Buil, Maria, Villarroel, Liste & Lopez, 2004). The feedlot is normally responsible for weighing the animals or classifying them by commercial type, choosing those suitable for transport, organizing the fasting of the animals and to coordinating the journey with the haulier and possible intermediate points to the slaughter plant (Miranda -de la Lama, Villarroel, Liste, Escos, & María, 2010). In terms of logistics and animal welfare, the feed lots should have pre-loading pens with access to food and water to separate the animals that will be transported at least one day before the journey (Villarroel et al., 2001). In that way, animals unfit for travel can be identified and separated (Becerril-Herrera et al., 2009). The loading facilities should be properly maintained and concrete or metal ramps should preferably include opaque side boards to avoid distractions during loading (Maria, Villarroel, Chacon & Gebresenbet, 2004). In this way, the loading process by the haulier will more effective and smooth, keeping the animals calm and reducing stress levels. These practices are especially important in routes covering many farms, feed lots or loading stops.

The stopovers (auction markets, storage centres, classification at logistics centres, health check points, and resting points or pre-export assembly depots) are where animals can be unloaded, weighed and classified to reduce production costs and improve strategic commercialization and livestock health schemes (Miranda-de la Lama, Villarroel, et al., 2010). Some centres only allow loading/unloading or include classification and the infrastructure to finish animals to an established commercial weight and/or re-distribute them too their farms. Pig production is quite standardized and has a long tradition of logistic planning (large integrated systems), which is extending too their species in parallel with the intensification process. Logistic stopover points may have negative effects on welfare since they include multiple loading and unloading operations, handling to classify by weight, gender, breed or commercial type, and preclude the need for social mixing or double transports in one day, a week or a month (Miranda –de la Lama, Villarroel & Maria, 2012). Other types of stopover points include export stations, livestock quarantine, auction markets, and resting stations (Fisher, Colditz, Lee & Ferguson, 2009).

In auction markets, livestock of multiple classes are sold for slaughter, breeding or further finishing (García-Flores, Higgins, Prestwidge & McFallan 2014). These markets play a key role in the livestock industry and within rural communities. They help establish competitive bidding so that farmers can get the best prices for their stock. The sale of live-stock at some of the larger markets is also associated with prestige with - in the industry. Auction markets provide a venue for important social gatherings within the farming community (Robinson & Christley, 2007). However, livestock markets and auctions have several logistical disadvantages since it is hard to ensure traceability and diseases can be disseminated easily (Bigras -Poulin, Thompson, Chriel, Mortensen & Greiner, 2006). Markets represent a potential risk for animal welfare as they can trigger stress in cattle, which in turn seriously affects the quality of their meat (Knowles, 1999; Romero, Uribe -Velásquez, Sánchez & Miranda –de la Lama, 2013). In a study of 18 cattle markets in the UK, the key welfare issues were found to be slips and falls during un loading, grading, moving up to and through the sale-ring, impacts during grading and at specific places when passing to and through the ring, slip sand falls during loading in calves, and refusal to load after the sale (Gregory, Benson & Mason, 2009). Animals get dirty, which also increases carcass contamination. Theirs k of lesions, stress and de-hydration is higher than on the farm (Oliveira, Guitian & Yus, 2007). For those reasons, many companies buy directly from slaughter plants or have developed associated farms that send animals to logistic classification centres where they are classified according to specific criteria (Miranda -de la Lama et al., 2009). Animals are often exchanged among different types of vehicles at stopovers for health and logistical reasons. Some specialized trucks load animals at the farms and transport them to logistic centres; others are used to go to slaughter plants (Averos, Martin, Riu, Serratosa & Gosalvez, 2008). Whatever the case, stopovers trigger physiological and behavioural stress responses that alter meat pH, colour and texture in calves (Gregory, 2008), pigs (Averos, Herrandez, Sanchez & Gosalvez, 2009) and sheep (Miranda-de la Lama et al., 2009). Although it is commonly assumed that as top over can be stressful, Miranda-de la Lama, Salazar-Sotelo, et al. (2012), found that direct journeys from farm to slaughter plants (3 hour-journey) can be even more stressful (affecting meat quality) than stopovers (3- journey hour and 1-stopover hour). Those results highlight the importance of an efficient management system to avoid the possible negative effects of a stopover, along with the need for the necessary infrastructure and trained personnel.

At the slaughter plant, vehicles often have to wait in line to unload. Queues at the slaughterhouse ’s delivery point frequently cause problems for drivers and for the slaughterhouse staff , creating a stressful work environment, which could also negatively affect the animal welfare (Gebresenbet, Ljunberg, Geers ,& Van de Water , 2004). National surveys in the UK have reported an average waiting time of 23 min with individual vehicles sometimes waiting as long as 3-5 hours to unload (FAWC, 2003). Then animals are distributed in pre-slaughter pens, followed by a lair age of variable duration, stunning and sticking. Waiting time to unload is usually not a problem in small plants but can be long in high throughput plants, affecting slaughter speed (Ljungberg, Gebresenbet & Aradom, 2007).The solution involves improved logistics. For example, in the UK some slaughterhouses have introduced scheduling procedures in an effort to ensure that animals can be off-loaded quickly. The route plans may include planned detours to avoid waiting at the unloading point and keep the truck moving in the surroundings of the plant (i.e. similar to airports). When vehicles move, animals are less stressed and the micro-environment may improve. This aspect is especially relevant when animals are subjected to long fasting periods, like pigs (Maria, 2008). That system works well and should be encouraged, particularly where there is limited lair age capacity. When lair age space, or the number of unloading points, is limited, vehicles may have to wait to unload. This situation could be exacerbated if there is a breakdown on the slaughter line, particularly where throughput has increased over the years but lair age capacity has lagged behind (FAWC, 2003).

Transportation andlogistics

The efficiency of animal transport, which can involve collecting from various farms, or queuing and unloading at the slaughterhouse, could improve when integrated with dynamic planning process that takes into account road conditions, weather, traffic conditions, transport time and distance (Aradom, 2012). Even under favourable conditions, livestock are exposed to arrange of potential stressors which may compromise their welfare, health and performance (Bak & Wajda,1997) due to changes in the thermal micro-environment, weather conditions, social mixing, handling, withdrawal of feed and water, vibration and acceleration and associated fatigue, loading and unloading stress and injury, noise and environmental pollutants (Mitchell & Kettlewell, 2008). Those aspects have been dealt with in a considerable amount of studies, where transport is defined as a stressful procedure that may compromise animal welfare (Knowles, 1995; Tarrant, 1990), affect meat quality (Maria, Villarroel, Sañudo, Olleta & Gebresenbet, 2003) and even increase mortality (Earleyetal., 2012). The exact causes of stress depend on the characteristics of each species, including the rearing system (Terlouw et al., 2008). For pigs, stress can be caused by fighting during mixing of pens, loading and unloading conditions, and introduction into the restrainer. Handling and novelty of the situation contribute to the stress reactions. For veal calves and adult cattle, disruption of the social group, handling, loading and sometimes unloading conditions, fatigue, novelty of the situation and, for calves, mixing with unfamiliar animals are known stress factors. Gathering and yarding of extensively reared lambs and sheep causes stress, particularly when shepherd dogs are used. Subsequent transport may induce fatigue, especially if sheep are commercialized through auctions or markets (Bourguet etal., 2010; Terlouwetal., 2008). We can minimize some of the biological cost of adaptation to transport by proper handling and loading /unloading procedures, driving smoothly along adequate routes with well-designed vehicles and reducing loading and unloading stops (Miranda de La Lama, Villarroel, Campo, et al, 2012). Factors mentioned above make transport a strategic activity in terms of animal welfare, logistics and their economical implications. The most relevant aspects of transport as a logistic activity will be revised below.

Transport cost

Transportation makes up a third of logistic costs and transportation systems have a great influence on the performance of logistic systems (Tseng, Yue & Taylor, 2005). Economic considerations associated with livestock transportation normally consist of direct costs associated with freight charges dictated by load size, hauling distance, difficulty in reaching pickup or delivery destinations, and any special handling that may be required (Speer, Slack & Troyer, 2001). Items such as vehicle depreciation, interest, tax, warehouse costs, auto insurance, salaries, fuel, maintenance and high way tolls may also be considered (Liu, 1998). Short-falls in terms of personnel and equipment have the potential to contribute additional costs to the transportation process. In consequence, any improvement in transport conditions will have an important effect on the final meat price (Maria, 2008). However, transportation costs can be reduced if farmers from one production area can organize themselves to use the same transport to markets or slaughter houses. By transporting in volume they stand a better chance of maximizing economies of scale compared to transporting individuals in small quantities (Shiimi, Taljaard & Jordaan, 2012).

The costs associated with transport extend well beyond direct freight charges. Data from the National Institute for Animal Agriculture suggest that 80 ,000 pigs die annually in the U.S. during transport. Assuming a $100 market value per hog, this equates to an $8 million annual loss to the pork industry, not including carcass disposal fees (Speer, Slack & Troyer, 2001). Apart from direct economic concerns, indirect effects on the environment are a growing concern in a carbon-constrained economy. Transportation is one of the main sources of livestock related carbon dioxide (CO_2) emissions and increasing glob-al livestock trade results in more fuel consumption for livestock related transportation (Soysal, Bloemhof-Ruwaard, & van del Vorst, 2014).

The haulier

Driving quality is affected by the ability, fatigue, driving style and attitude of the haulier (Cockram et al., 2004).

Ability includes how the haulier controls the vehicle, for example, change of direction or engine braking. Fatigue caused by sleep loss or circadian rhythm disturbances is widely cited as a contributing factor in motor vehicle crashes. In an Australian study with 32 livestock hauliers, Darwent, Roach and Dawson (2012), found that the amount of sleep was 6.07 h/24-h period was consistent with that reported of other truck drivers, but less than the recommended optimum of 8 h/day. The sleep behaviour exhibited by drivers was nonetheless generally consistent with that expected on the basis of normal sleep physiology. That is, drivers usually initiated main sleep periods at night and occasionally supplemented this with a daytime nap. The occurrence of some especially long sleeps in excess of 12 h is unusual, but this may merely reflect a behavioural lull that encouraged sleep in the absence of immediate work demands and competing social and/or familial stimuli. Style refers to how the vehicle is driven and can be evaluated by lateral and longitudinal speed and velocity patterns. Driving style is affected by age, since young drivers (18-27 years of age) are more imprudent while older ones (above 55) maybe more distracted due to chronic diseases associated with the profession. It seems that the ideal age of a driver is between 28 and 54 years of age, because there is a combination of experience and good health (Duke, Guest & Boggess, 2010; Häkkänen & Summala, 2001). A bad attitude threatens efficiency because negative behaviours (attributed to frustration, fatigue and stress) make drivers unhappy and are associated with impaired driving (Miranda -de la Lama, Sepulveda, Villarroel & Maria, 2011). It is clear that those factors can increase the likelihood of road traffic accidents (Woods & Grandin, 2008). Aspects such as acceleration, braking, and cornering, which are under the control of the driver, affect an animal's ability to main ta in postural stability and impede adequate rest of the animals during the journey, increasing their excitability, reactivity and lesions (Cockram et al., 2004). However, driver "experience" may sometimes be a risk if it is based on mistaken or misused management techniques, without knowledge of new concepts of animal welfare and behaviour. On-going driver training based on these new concepts should be a priority in the logistic chain. Training should cover notions of behaviour and animal welfare, as well as practical implications of adequate braking and acceleration techniques, to avoid sudden acceleration and changes of direction, which will increase the proportion of "downers" (Schwartzkopf-Genswein, Haley, Church, Woods & O' Byrne,2008).

Hiring a driver with appropriate training and a positive attitude to- wards animal welfare can have appositive effect on the logistics chain, and product quality (Miranda-de la Lama, Villarroel, et al.,2010; Peetersetal., 2008). For example, in France, since 1990, hauliers transporting pigs have received specialized courses (two-day sessions organized by the ITP, Institut Technique de Porc, Paris, France) on the importance of good handling practices from an economic point of view as well as in terms of public perception (i.e. the image consumers have of pig production). After these training sessions began, many slaughterhouses recorded decreased levels of skin damage (Chevillon, 1998). Hauliers should be trained to perform checks during the journey to attend to downers or injured animals that are unable to stand. Besides ensuring the truck 's mechanical and technical conditions, hauliers should notify their company before starting a new journey (Schwartzkopf-Gensweinetal., 2008). Proper payment systems with premiums for drivers with excellent qualifications can provide incentive. Developing a specific point system of licenses to transport animals may be another way to promote good practice.

4Loading density

Loading density during transport is one of the main factors that influences welfare and comfort. From an economic point of view, densities can increase or reduce unit costs of operation (De la Fuente et al., 2010). High densities may make travel un comfortable, since the limited space prevents animals from positioning themselves freely and makes it difficult to maintain balance, especially on long journeys (Gallo et al., 2005). When densities are low, individuals have more space to lie down and move but if driving or road conditions are poor, it may be easier to lose control of the vehicle (Eldridge & Win field, 1988). Low and high densities affect the incidence of bruising and other lesions; so most guidelines suggest an average density. Space required per animal during transport can be defined in three ways: as surface area of flooring per given weight(m2/100kg), as live weight (kg) perm 2 of flooring (kg/m2) and surface area per animal(m2/animal). The later is not useful since it does not take into account individual weight variance, but the minimal area that an animal occupies can be calculated in terms of weight class. For animals of the same species and commercial category (i.e. size and weight) (P), linear measurements will be proportional to the cube root of body weight (P1/3). Animal surface area will be equal to the linear mean square(P2/3), which is equal to P0.66, used in the equation suggested by Petherick and Phillips (2009), A= 0.020 W0.67 (where A= is the availability of space and W= live weight (kg)raised to a power of 0.67, that is, the metabolic weight). This formula is based on the concept that the total area occupied by an animal is proportional to its surface area. Thus, a 400 kg cattle should be transported in an area of 1.16 m2; a 100 kg pig at 0.46 m2 and a 50 kg sheep at 0.26 m2.

Route planning and optimization

The transport of live animals to slaughterhouses is a classical logistics problem, where a number of vehicles with limited capacity must collect animals at diverse farms and bring them in to provide a steady flow of animals at the slaughterhouse (Gribkovskaia, Gullberg, Hovden & Wallace,2006). A typical vehicle routing problem deter-mines the least- cost routes from a set of geographically dispersed farms to slaughterhouse or logistic centre (auction markets, storage centres, classification at logistics centres, or pre-export assembly depots). The routes must be generated in such a way that each points 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 truck (Bochtis & Sørensen, 2009). Furthermore, in the livestock collection problem, there are two kinds of time windows, and they occur for two different reasons. The first type occurs because the farmer is not always at home waiting to deliver animals. Therefore, he or she needs to 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, and occurs because the animals need to be slaughtered within a certain time interval in order to have the desired weight at slaughter (Oppen & Løkketangen, 2008). Additionally, as the number of slaughterhouses is being reduced, the need for cost effective transportation increases substantially as does the complexity of route planning. The fact that many slaughterhouses are now specialized in terms of animal types has the same effect (Ljungberg, Gebresenbet & Aradom, 2007). Moreover, the ease of animal trades among countries, facilitated by international agreements (i.e. NAFTA and EU freetrade), the improvement of road networks and the technical characteristics of vehicles, has led to an increase in international road transport (Dalmauet al., 2013). Production systems are more stratified due to specialization, creating subsystems or links that are sometimes widely spread geographically. Consequently, the transport variables of the system increase and the majority of animals raised in these systems will undergo more than one journey in their lifetime. For these reasons, it is important to develop effective logistics and a dynamic planning process that takes into consideration road conditions, climate, traffic, transport time and distance, and queuing at the slaughter house for unloading, all of which are potentially stressful for animals (Ljungberg et al., 2007). Gebresenbet and Ljungberg (2001), studied the optimization of 15 routes, from loading to slaughter, using Logi X software. They compared previous journeys and optimized them, finding that travel distance could be reduced by 18% and travel time by 22%. In an-other study, Gebresenbet, Bosona, Ljungberg, and Aradom (2011), using the same software, organized 500 farms creating 30 routes and a 42 % reduction in travel distance, with 37% travel savings.

An important issue to be considered in any route planning is the overall condition of the chosen roads. During transport, animals are ex- posed to vertical, lateral and horizontal vibrations. Unpaved roads in poor condition or paved but winding roads transmit more vibrations (Gebresenbet, Aradom, Bulitta & Hjerpe, 2011), which causes discomfort, shifts the animal's centre of gravity and may cause them to lose balance (Miranda -de la Lama, Monge, et al., 2011). Shifting weight on curves or steep slopes can cause rollovers, especially in trucks transporting pigs (Miranda-de la Lama, Sepulveda et al, 2011).

Journey length

Nowadays distances for road transport of farm animals to other farms or a slaughterhouse are increasing due to the economic bene fits and greater opportunities of long distance and international trade, improved infrastructure and increased demand for live animals for fattening and slaughtering (Lambooij, Vanderwerf, Reimert & Hindle, 2012). Long distance animal transport is more likely to compromise animal welfare and meat quality than shorter journeys (Pérez et al., 2002).

For example, long journeys are physically demanding since animals spend long periods of time standing and trying to maintain their balance (Gebresenbet, Aradometal., 2011). However, it is not journey duration per se but the associated negative aspects, which are the cause of the observed welfare issues (Miranda -de la Lama, 2013). Factors such as fluctuating temperatures, lack of food, water and rest are all exacerbated by length of exposure, and thus journey duration (Nielsen, Dybkjær & Herskin, 2011). Consequently, provided conditions are good, most healthy and fit farm animals could be exposed to long transport durations without necessarily compromising their welfare and quality of the products. In contrast, animals in a poor state of fitness should not be transported at all (Dalmau et al., 2013; Nielsen et al., 2011). Cockram (2007), suggests that animal welfare is compromised after a certain duration, but emphasizes, that there is a lack of data to substantiate these premises and to quantify thresholds.

The World Organization for Animal Health (OIE) has recognized the importance of maintaining a minimum standard of welfare during road transport. According to the OIE (2012), road transport guidelines establish the maximum duration of a journey should be determined according to factors such as: a) the ability of the animals to cope with the stress of transport (such as very young, old, lactating or pregnant animals); b) the previous transport experience of the animals; c)the likely on set of fatigue; d) the need for special attention; e) the need for feed and water; f) the increased susceptibility to injury and disease; g) space allowance, vehicle design, road conditions and driving quality; h) weather conditions; and i) the vehicle type used, terrain to be traversed, road surfaces and quality, skill and experience of the driver.

Within the EU, free movement of animals from one-member state to another has stimulated an increase in long distance travel between farms or from farm to slaughterhouse (Lambooij et al., 2012). For these reasons, The European Community (DOCE, 2005) has established maximum journey durations. The regulation provides for different times depending on the type of animal: un weaned animals, i.e., animals still drinking milk (maximum of nine-hour journey, followed by one-hour rest to enable the animals to drink, followed by a further nine hours of journey). For pigs: a maximum of 24-hour journey, provided there is continuous access to water; cattle, sheep and goats: a maximum of 14 hours, followed by a one-hour rest to enable the animals to drink, followed by a further 14 hours of travel. The above sequences may be repeated provided the animals are unloaded, fed, watered and rested for at least 24 hours at an approved control post. Further provisions for 'improved' vehicles such as forced ventilation and direct access for attendants to provide appropriate care were added in 1998 by Council Regulation EC/ 411/98 on additional animal protection standards for road vehicles used for the carriage of livestock on journeys exceeding 8 h. Recently, over 1 Million EU citizens signed the Malta Manifesto (http://www.8hours.eu/manifesto_of_malta/), askingforagenerallimitontransporttimesto8 hours. The European Parliament has adopted a written Declaration in support of the 8-hour limit.

In the past few years, the concerns and perceptions about animal welfare of consumers in western countries such as the EU has begun to influence new transport regulations in other countries, especially where meat is exported to EU markets (i.e. Uruguay, Brazil, Chile, Argentina or Australia). Australia is the largest exporter of red meat in the world and has specific Model Codes for the road transport of sheep, cattle, and pigs. These provide guidance on maximum journey times, animals unfit for travel and maximum food and water deprivation times. In lambs and mature sheep the limits are 24 -36 h and 36 h without food or water, extended to 48 h if followed by a 24 h rest. Mature cattle can be transportedfor36-48 hours and calves for 24h. In the case of pigs, after 24 h there should be a rest period of 12-24 h; all animals should be fed and watered at least once in each 24 h period, or more frequently if young (Fisher& Jones, 2008). Canada, the United States and Mexico, integrated in the North American Free Trade Agreement (NAFTA), have varying laws, codes and regulations, and there are significant shortcomings in scope and enforcement, which present challenges to regulate journey duration. For example, Canadian drivers transporting pigs from Canada to California (where they will be shipped to Hawaii) are not governed by Canadian transport regulations after crossing in to the USA. Similarly, the USA's28 h time limit fails to apply to livestock such as pigs and cull ewes transported to Mexican slaughterhouses after they cross the Mexican boarder (Engebretson, 2008).

4.6. Mixed transport: road and sea, rail or air

The economic value of exported livestock worldwide has been growing by about 4% per year (Phillips, 2008). Much of the export process involves transportation by ship (Phillips & Santurtun, 2013). The major worldwide region sex porting livestock by ship are Australia, USA, southern South America, the Horn of Africa and Ireland (Phillips, 2008). For example, Australia is the leading exporting country, sending total of 2,529,028 sheep and 718,025 cattle overseas in 2011, mainly to the Middle East and Southeast Asia, respectively (DAFF,2012; Fisher& Jones, 2008). Currently, there are no international regulatory standards to ship livestock by sea but welfare guidelines have been developed by the World Organization for Animal Health (OIE) in 2003–2004 (Schultz-Altmann, 2008). Those were subsequently incorporated into the OIE Terrestrial Animal Health Code (Norris, 2005), which includes minimum animal welfare and health standards during the pre-journey, loading, journey itself, unloading and post-journey handling stages of sea transport (OIE, 2012). However, the recommendations are necessarily general because of the diverse range of participant countries, and they do not provide specific and measurable animal welfare indicators. Moreover, they are not compulsory for livestock exporters (Phillips & Santurtun, 2013).

The trend towards more international trade and the increasing amount of transport methods has generated complex operations. In some cases, livestock vehicles are loaded onto ferries, or animals can be un-loaded from the truck and placed onto mother ships. In most of the latter journeys, fattening is completed in another country. For instance, Earley et al. (2012) have studied the effect of mixed journeys of bulls born and raised in Ireland, which were transported by road to Spain and Italy. That trade exists due to the scarcity of animals for fattening in Southern Europe and the sensory preference of southern European consumers for meat from animals fattened on cereals (Oliver et al., 2006). Live sheep export from Australia to the Middle East involves multiple stages and significant stressors over the three to four weeks of the journey, from mustering in the paddock to arrival in a feed lot or slaughterhouse at the destination country (Santurtun, Moreau & Phillips, 2014). There are also mixed transports of stock, as in the Middle East and especially the Arabian Peninsula, who are the largest importers of sheep, goats, and cattle from Australia, New Zealand, Uruguay, Argentina and China (Norris, 2005). In those journeys, animals are loaded onto mother ships where they are stabled (Norris et al., 2003). In Chile , where mixed transport is quite common , sheep are transported by truck for 10 to 12 hours , the truck is placed on aferry and then continues a 10-hour road journey to the slaughter plant (Tadich , Gallo, Brito,& Broom , 2009). In Europe , female pigs used for genetic stock improvement can be transported from Scotland , crossing the English Channel by ferry to France and sent to the south of Spain (Villarroel, Barreiro, Kettlewell, Farish & Mitchell, 2011). An- other similar case is the transport of calves from the United Kingdom to Italy (Norris et al., 2003). The requirements for rail transport are essentially similar to those for road transport, focus sing on standards for vehicles, rest periods, and times for feeding and watering (Sossidou, Broom, Cziszter, Geers & Szűcs, 2009).

Rail transport may have less of a negative effect on welfare com - pared with road transportation, because a handler attends the animals and there are fewer changes in direction. Rail is, however, generally more expensive than road transport, which is the most common form of transport for cattle in Europe. In the USA, journeys for beef calves are very long (typically 1000 to 3000 km), when transported to a feedlot (Phillips, 2002). In Australia all livestock have been transported by road within the country, except for some long-haul rail transport of cattle in Queensland, where cattle are trucked by road and then by rail over 1400 km to meat plants (Wythes, Shorthose, Schmidt & Davis, 1980). Rail transport may be less common since animals have to be transported to a station and reloaded, thus increasing the adverse effects of loading, while possibly lengthening total journey time (Lambooij, 2007).

Air travel is expensive and limited to the transport of breeding animals, horses (see: Leadon, Waran, Herholz & Klay, 2008), zoo animals (see: Snyder et al., 2012), and day-old-chicks. It is usually reserved for excessively long journeys that would be too stressful by road, e.g. cattle sent as aid from Europe to developing countries, or very valuable cattle, such as prize bulls. Careful consideration should be given to the effects of changes in air pressure and temperature on ruminants and pigs (Lambooij, 2007; Phillips, 2002). The regulations produced by the International Air Transport Association (IATA) provide the worldwide standards for transporting live animals by commercial airlines, providing specific guidelines on container sizes for different species. The Australian Standards for the Export of Livestock by Air (2008), includes the following criteria to assure fitness for travel on long journeys: treatment for internal and external parasites, pre-flight mixing of animals before loading to establish social hierarchy, allowing the animals to become accustomed to being handled and to close confinement, and all owing animals to become accustomed to the type of feed.

Road accidents

Road accidents involving livestock can be caused by many factors but often lead to important financial losses and injuries to animals and humans. Due to their nature, they require immediate and effective attention, and coordination between policemen, firemen, hauliers, owners and veterinary services (Miranda -de la Lama, Sepulveda, et al., 2011). Livestock vehicle accidents are associated with a series of factors concerning the driver, the vehicle and the road (Joshua & Garber, 1992). The factors involving the haulier include age, alcohol consumption, fatigue, chronic health problems, imprudence (Häkkänen & Summala, 2001) and lack of training in livestock transportation (Cockram et al., 2004). With regard to the vehicle, the most frequent factors associated with increased accidents are mechanical failures, problems with trailer- truck balance (Braveretal., 1997), and the weight and size of the vehicle (Björnstig, Björnstig & Eriksson, 2008). Finally, climatic characteristics, topography and highway design also contribute to accidents (Miaou & Lum,1993).

In a study conducted in the USA and Canada, Woods and Grandin (2008), found that the most affected species were cattle (56%), and pigs (27%). The majority of the accidents were due to driver error or adverse weather conditions, mainly in non-articulated trucks. In another study, Miranda -de la Lama, Sepulveda, et al. (2011) observed that 58 % of accidents recorded in Spain corresponded to pigs, 30% to cattle, and 5% to sheep trucks . Cattle accidents were mostly frontal collisions in small vehicles while in pigs, there were more rollovers in double semi-trailer tractors. Both studies agree that one of the main causes of accidents is driver fatigue, which is a result of multiple factors including intense working hours, badly design routes, long journeys, onerous delivery schedules and the adverse effect of these schedules on hauliers sleep.

The involvement of veterinarians and rescue corps should be organized by governmental emergency systems, which must prioritize relief to humans, followed by animals (Woods & Grandin, 2008). Animals that survive are often in a state of pain, anguish and fear, so are more are difficult to handle (Woods & Grandin, 2008). Traffic safety must be focused in diminishing vehicle speed around the accident and control of traffic volume, because loose animals on the highway may cause more accidents. Subsequently, restraining or regrouping of surviving animals and quantification of main damages should begin, to prioritize rescue, in terms of harmed and unharmed animals. In situ or ex situ euthanasia should be considered according to the public safety risk, degree of lesions and proximity of slaughterhouses for emergency slaughter. Once those measures are performed, the number of dead animals and debris should be quantified as well as corpse removal strategies. Vehicles should carry equipment to deal with these situations, including ropes, flashlights, blankets, reflective signaling cones, buckets, an emergency telephone list, accident insurance and a first-aid kit.

Livestock truck specifications

Livestock trucks must be designed, constructed, maintained and operated so as to protect the animals from inclement weather, extreme temperatures, adverse changes in climatic conditions, and injury. In general, four types of specialized vehicles are used: small trucks (≤ 3 ton), single units (4 m × 13 m), semi-trailer tractors (4 m × 18 m: one trailer) and double semi-trailer tractors (4 m× 20 m: two trailers). The choice of vehicle will depend on the type of livestock to be transported, specific demands of the market, journey length and geographic region. The credit systems of the country and the possibility to obtain subsidies or incentives to renew the fleet (i.e. European Union) also condition the choice of vehicle to be used. In a national inventory of livestock trucks in the USA and Canada, 30% were single units ,45% semi -trailer tractors and the remaining 25% double semi-trailer tractors (FHA, 1999). In Europe, the most common trucks are single and semi-trailer tractors (Miranda-de la Lama, Villarroel, et al., 2010). However, in Australia, double semi - trailer tractors are the most common, which, in some cases, have three trailers (road train) to cover long distances on mainly straight thigh ways (Fisher et al., 2009).

Floors, walls and divisions

The structures and materials used to make floors, walls and dividers for livestock vehicles must be suitable for the animal, be able to bear their weight, and help avoid injuries. The motion of the floor surface in a transporter depends on the vehicle's suspension, load, floor rigidity, engine speed, transmission, road speed, road surface, and wheel imbalance. Most livestock vehicles are not designed to reduce vibrations for the animals, which are probably much higher than for the driver (Peeters et al., 2008). Therefore, the floors on the vehicle should have a non -slip surface to reduce the risk of falling, made of metal or wood (Lapworth, 2008). Slats or boards refer to the use of either plastic, fiberglass or plywood pieces which can be inserted down the side of the trailer to cover perforations, thereby affecting air exchange between the interior and exterior of the vehicle during cold weather (Schwartzkopf-Genswein et al., 2012). In some countries, handlers use grids of plastic for sheep and pigs; however, they tend to break more easily than metal flooring and can cause foot lesions (Mcgreevy, George & Thomson, 2007). There must be enough bedding on the floor to absorb excretions, unless they can be removed by another efficient manner or are removed regularly. Bedding, which usually includes the use of woodchips, sawdust, cellulose or straw is recommended as a best practice for shipping animals when ambient temperatures are below 10 °C (Schwartzkopf - Genswein et al., 2012). Although providing bedding is a common practice, it can make the floor more slippery and make cleaning the trailer more difficult, increasing the risk of pathogen dissemination (i.e. Foot and Mouth Disease; Hutchison, Walters, Avery, Munro & Moore, 2005; Martínez-López, Perez, De la Torre& Sánchez-Vizcaíno Rodríguez, 2008). Bedding helps absorb livestock manure and maintain warm temperatures in cold climates. A slight inclination of the floor canal so help to provide balance throughout the journey. The internal walls of the vehicle should include communication vents to the outside (Mitchell & Kettlewell, 2008). The internal compartments are essential for balancing the load, and it is important that their rounded edges be covered with padded plastic prevent lesions and bruising.

Temperature, humidity and ventilation

The main determinants of the internal thermal micro-environment in livestock container are the external climatic conditions, the ventilation regime, internal air flow patterns and the total heat and moisture production of the animals (Norton, Kettlewell & Mitchell, 2013). Theoretical estimations indicate that atypical trailer (13 × 6 m) of animals at the recommended densities and approximate commercial weights of 500 kg for cattle, 100 kg for pig sand 30 kg for sheep, produces 13400, 11 500 and 8 000 watts of heat, respectively (Kettlewell et al., 2001). Animals may lose large quantities of heat and fluids during transport due to panting and sweating. Those losses are conditioned by air temperature inside and outside of the truck during the journey (Villarroel et al.,2011). One possible explanation is related with enthalpy, which is the heat energy of the air surrounding the animal and dictates the degree of heat loss inside the trailer (Villarroel et al., 2011). Enthalpy can be calculated from the equation: h= S x t d b + H x h w where Sis the specific heat of dry air, 1004 kJ / (kg.°K), td bisthedry bulb temperature, His the specific humidity endwise the enthalpy of water vapour (kJ/kg). Enthalpy scales are expressed as kJ/k go f dry air. As a comfort index, enthalpy indicates environmental conditions related to heat stress suffered by animals. This variable is often used as a comfort indicator at the truck level, indicating a quantity of thermal energy to be removed from the environment to enable adequate transport thermal conditions (Rodrigues, da Silva, Vieira & Nascimento, 2011). However, relatively little is known about time derivatives of enthalpy on the farm, and how they may change during transport and at the slaughter-house. Abrupt changes in the enthalpy pre-slaughter may have direct and more serious effects on welfare than degree differences in temperature alone (Villarroel et al., 2011). High dry climatic temperatures during transport causes stress and de hydration, however there is evidence that dehydration in journeys during cold weather is similar or worse than under hot conditions (Miranda -de la Lama, Rivero, et al., 2010). In dry cold weather, animals tend to produce heat to keep body temperature within its thermo-neutral zone. After loading, and at high stocking densities, the humidity and temperature within the truck rise quickly. This stimulates evaporative heat loss in the animals by panting and sweating; creating a microclimate that favours dehydration (Caulfield, Cambridge, Foster & McGreevy, 2014; Miranda -de la Lama , Salazar - Sotelo, et al.,2012).

The interrelation between air temperature and humidity is important from the point of view of animal welfare during livestock transport (Fisher, Stewart, Duganzich, Tacon & Matthews, 2004). The temperature humidity index (THI) has been used since the early 1990 s. It accounts for the combined effects of environmental temperature and relative humidity, and is a useful and easy way to assess the risk of heat stress. THI is calculated from air temperature and relative humidity using the following equation: THI= (Dry bulb temperature °C) + (0.36 x dew point temperature °C) + 41.2. The THI values are used to assess environmental conditions that may cause thermal stress problems for cattle, sheep, goats and pigs: normal, ≤ 74; alert, 75–78; danger, 79–83; emergency, ≥ 84 (Silanikove, 2000).

The effective control of the microclimate inside a trailer can improve animal welfare (Kadim, Mahgoub, Al-Kindi, Al-Marzooqi & Al-Saqri, 2006). Ventilation systems are an important element in livestock truck design. They can be can be passive (vents) or active (fans) (Miranda-de la Lama, Villarroel, et al., 2010). Passive ventilation can be increased by increasing the quantity of vents along the chassis, although in some models there are devices to block the vents (Dalley, Baker, Yang, Kettlewell & Hoxey, 1996). The main difficulty with passive ventilation is due to the variability of outdoor climate conditions, the travel ling speed and geometry of the vehicle, as well as the nonlinear relationship between the airflow through the openings and the ventilation efficiency at animal level (Norton, Kettlewell & Mitchell, 2013). This system is variable and depends mainly on the exterior design and the average wind velocity (Baker, Dalley, Yang, Kettlewell & Hoxey,1996).

Additionally, there is very little control over the ventilation regime, except for closing and opening the vents, which may require stopping the vehicle to make the relevant adjustments (Hoxey, Kettlewell, Meehan, Baker & Yang, 1996). For instance, in winter, when the majority of vents are closed, the concentration of gas and humidity may represent a risk for the animals (Kettlewell et al., 2001). Intemperate climates or areas with marked winters and summers, trucks with grates and bars or open vehicles are common, providing ample ventilation, al-though animals are exposed to rain. The use of fans may ensureade-quate ventilation for all animals during the journey. The natural internal air flow will be determined by the location of the entries and exits and the differential pressures between them. An ideal design will contemplate a series of extraction fans placed in low pressure regions of the trailer to improve performance when the truck is moving, and vents in sites where airflows above the animals (Kettlewelletal.,2001). Those systems are commonly controlled by an automatic sensor and are found in cattle, pigs and sheep trucks. Recently, the European Food Safety Authority (EFSA) on the welfare of animals during transport recommended the development of water spraying devices to ensure pig comfort during transport (EFSA, 2011). Despite the interest in water spraying as a means to reduce thermal stress in pigs during transport, studies show that reducing stress response and improving meat quality (Nannoni et al., 2014). Cattle transport vehicles in North America typi-cally have a variety of perforation patterns, depending on the manufacturer, which are used for ventilation and most trailers have 2 roof hatches that can be opened for increased ventilation. The doors at the back of the trailer are solid and have no perforations. Ventilation within those trailers is passive and there is no equipment to provide feed or water to the animals onboard (Schwartzkopf-Gensweinetal.,2012).

Loading and unloading truck facilities

In many competitive logistic chains in several countries, some vehicles are adapted with well-designed ramps while others have hydraulic lifts on tailgates. For example, in the European Union, many sheep /goat and pig trucks have factory equipped hydraulic lifts, which are used as ramps or elevators. These lifting platforms have safety barriers so as to prevent animals from falling or escaping during loading and unloading operations. Elevator ramps are most useful in sheep and pig transport, while folding ramps are less practical, but much cheaper. In many countries livestock trucks 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 pigs and calves and 26 degrees 34 minutes or 50 % to the horizontal for sheep, goat and cattle other than calves. Where the slope is steeper than 10 degrees (17.6 % to the horizontal), ramps should befitted with a system, such as foot battens, which ensure that the animals can climb or descend without risks or difficulties (EFSA, 2011). In developing countries, hydraulic tailgate lifts or aluminum trailers are often not appropriate or available. Therefore, simple improvements can make a great difference, such as building well-designed ramps for loading and unloading and training people in animal behaviour and low stress hand ling methods(Grandin,2008).

Additional equipment

In Europe, most trucks have pneumatic suspension and velocity limitation devices (up to 90 km/h) (Miranda -de la Lama, Villarroel, et al., 2010). There is also an increasing trend to use Global Positioning System (GPS), mostly to find alternative routes when necessary. A few research reports are available on the development of surveillance systems for animal transport. A transport surveillance system has been developed (Geers, Puers, Goedseels & Wouters, 1997), which integrates the following information: individual identification of animals, (un) loading place and time, temperature and movement. These data are collected by telemetry and GPS, and are transmitted to a dispatch centre by Global System for Mobile Communication (GSM). Gebresenbet, Wikner, Van de Water, Freson, and Geers (2003) developed as mart animal welfare surveillance system to monitor environmental conditions (temperature, relative humidity, vibration) in the vehicle, as well as animal behaviour, driving performance and dynamic route planning, where data could be transmitted to the destination using a GSM system. Likewise, it is essential to have at lea stone means of communication onboard, such as a radio or mobile telephone with a list of emergency numbers.

Effects of poor logistics in animals and quality product

Lack of effective communication infrastructure and information fl ow can increase risks in the pre -slaughter logistic chain. In order to counteract the logistical risks, more attention should be given to develop effective logistic technologies and efficient logistic management (supplemented with training) throughout the pre-slaughter logistic chain (Bosona & Gebresenbet, 2013). Poor logistic technology and management clearly result in greater morbidity, mortality, live weight losses, carcass bruising and meat quality defects (Paranhos da Costa, Huertas, Gallo & Dalla Costa,2012).

Morbidity

Young animals are especially vulnerable to transport and pre - slaughter stress. Naive immune systems and lack of exposure to new environments make them more vulnerable than adult cattle (Swanson & Morrow-Tesch, 2001). Concerns about the welfare of cattle during and after transport generally increase with their economic value (Knowles, 1999). Most morbidity and mortality is a result of the number of markets the young animals are shipped to, the specifics of each dealer, and weather during transport (Knowles, Brown, Edwards, Phillips & Warriss, 1999). The most common losses during transport can be divided in three categories: injured animals, sick animals and dead animals (Pilcher et al., 2011). In the first two categories, those that are able to walk and be isolated in quarantine corrals at the slaughter plant should be distinguished from others that must be slaughtered immediately after unloading. The most common lesions during transport are bruising, lameness, and dislocations (Minka & Ayo, 2007). Those lesions are associated with mishandling during loading and unloading, or badly designed or poorly kept trailers, ramps and alleys (Miranda -de la Lama, Villarroel, Maria, 2012). Fractures are among the extreme injuries that occur during transport. Those are rare in cattle, sheep, pigs or horses but could result from poor loading or unloading facilities and cruel or poorly trained staff who are attempting to move the animals (SCAHAW, 2002).

Several studies indicate that a combination of different stress factors during the journey may have repercussions on the health status of the animals. In 3-hour trajectories with lambs, with severe vibrations on unpaved roads, an increase in the neutrophil/lymphocyte ratio (N/L) of up to 52 % has been observed, which suggests immune - suppression, compared to using paved roads (Miranda-de la Lama, Monge, et al.,2011). Recently weaned calves are more apt to succumb to bovine respiratory disease –BRD– (complex of diseases caused by Pasteur ell a species, bovine respiratory syncitial virus, infectious bovine rhinotracheitis virus, and parain fluenza virus 3), post -transport previously weaned animals (Barnes, Carter, Longnecker, Riesen & Woody, 1975), so they should not be transported if less than 4 weeks old (Knowles, 1995). One solution to this problem is to precondition animals before transport, to prevent morbidity and mortality caused by bovine respiratory disease complex. Common components of preconditioning programs include weaning and holding on the ranch 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 & Galyean, 2007). The major bene fit of preconditioning is separating the occurrence of stressors such as castration, dehorning, weaning, vaccination, transport and marketing over time (Cole,1985). In adult animals, sub-clinical viral infections may make them more susceptible to secondary bacterial infections that can be fatal during or after transport (Brogden, Lehmkuhl &Cutlip,1998).

Mortality

Animals can die during transport for several reasons. The main causes of death in cattle are heat stroke, trauma and respiratory disease (BRD) (Norris et al., 2003). In pigs, the main reason is hyperthermia (overheating), especially during summer (Maria, 2008). Inadequate ventilation in transport vehicles has a clear effect on transport mortality. Nielsen (1981) showed that mechanical ventilation in single decked transport vehicles reduced transport mortality by almost 50 % (from 0. 046 % to 0.024 %). The proportion of pigs that die during transport in the EU has been estimated to range from 0.033% to 0.5% (Warriss, 1996). More than 70% of the deaths occur on the truck and 30% after unloading at the slaughterhouse. An average mortality rate of 0.25%would represent more than half a million animals per year (worth approximately € 60million) (Maria, 2008). In the case of sheep, Makin, Perkins, Curran and House (2009), studied the mortality rate during road transportation in Australia and the rate of rejection in alive pre-export assembly depot, finding the overall incidence of mortality on arrival was 6.54deaths per 10,000 sheep. The overall incidence of rejection on arrival was 47.97 deaths per 10,000 sheep. This study demonstrated that heavy sheep and those transported for long distances were more likely to perish during road transportation and also to be rejected from the consignment at arrival. In mixed journeys (terrestrial and marine), mortality may be a direct indicator of transport conditions and logistics since long journeys by ship can cause chronic stress (Higgs, Norris & Richards, 1991). For instance, Norris et al. (2003) observed a mortality rate of 0.24% in 4 million cattle transported by sea from Australia to Middle East and south Asia. They also observed higher mortality in long journeys (Middle East, 0.52 %) compared to short journeys (southAsia,0.13%).

Live weight losses

It is recognized that transportation will decrease body weight of animals depending on the fasting time and water deprivation. In one study (Wythes et al., 1980), steers were trucked by road and then by rail over a total distance of 1420 km. The animal lost 10% of their live weight, but 40% of that was recovered when they had a chance to drink. Rehydration increased hot carcass weight from 369 kg to 383 kg, and this gain was due to arise in the water content of the muscle. In the case of small ruminants, animal age and duration of the journey have an important effect on weight loss. For example, in 35–40 day-old recently weaned lambs (commercial category: suckling lambs), subjected to 30 m and 5 h journey, there was no weight loss (De la Fuente et al., 2010). In lambs older than 100 days, no weight loss was found after a 3-hour journey or even two journeys in one day (4–5 hours; Miranda -de la Lama, Villarroel, et al., 2010). However, in 6, 12 and 24 month old animals, afteran8-hour journey, weight loss increases withage,7.18%,9.04%and 9.57%, respectively (Zhong, Liu, Zhou, Sun & Zhao, 2011). In 4–5-year- old goats, 12, 30 and 48 h journeys de- creased live weight by 4.9%, 9.8% and 12.1%, respectively (Fisher et al., 2010). These results suggest that younger animals lose less percentage weight during transport.

Carcass damage

Bruising can affect carcass quality and decrease value. It can also be used as a welfare indicator for audits (Grandin, 2010). Bruises are tissue lesions with vascular rupture, which collect blood and serum, developed after the application of force with an object (Strappini, Metz, Gallo, &Kemp, 2009). They are indicators for detecting basic logistic chain failures, because they help to identify the source of problems, such as electric prod usage, abusive stockman ship, social mixing, rough edges or drop gates (Miranda -de la Lama, Villarroel, Maria, 2012). For example, in many emergent countries, a high incidence of cattle bruising has been observed in industrial slaughter plants, e.g. Uruguay (55%; Huertas et al., 2003), Brazil (84%; Andrade et al., 2008), Colombia (37.5%; Romero et al., 2013), Mexico (97%; Miranda -de la Lama, Leyva, et al., 2012), Namibia (90%; Hoffman & Lühl, 2012), although much lower rates have been reported in some countries with standards on animal welfare, i.e. Chile(9–21%,Strappini, Frankena, Metz, Gallo & Kemp, 2010).

The presence of horns as well as the gender, age, breed or temperament of animals may determine the incidence and severity of bruising (Strapping, Metz, Gallo & Kemp, 2009). Especially in cattle, males are more prone and younger animals have fewer lesions than adults (Jarvis, Selkirk & Cockram, 1995). Poor road conditions and long journeys also increase bruising, with a greater probability of falls and impact injuries. Similarly, lair age time is positively related with bruising in cattle (Warriss, 1990), sheep (Cockram & Lee, 1991), pigs (Fraqueza et al., 1998), and deer (Jago, Hargreaves, Harcourt & Matthews, 1996). Romero et al. (2013), studying a cattle slaughter house found that an of 18 to 24 h lair age at the slaughterhouse increased bruises twice as much as 12 –18 h lair age, suggesting that bruises are conditioned by risk factors during lair age such as poor handling practices, high densities, badly designed installations and mixing of animals from different origins (Marahrens et al., 2011). Intermittent stops during transport are a risk factor for the presence and /or increase in the incidence of bruises on carcasses (Romero et al., 2013). Social mixing, violent handling and pre-slaughter waiting quality are often over looked as sources (Miranda-de la Lama et al., 2009), but bruising can also be caused by poor conditions at the farm (Paranhos da Costa et al., 2012). In a study conducted in Brazil on pigs, Dalla Costa et al. (2009) reported that 53.7% of pigs already presented skin lesions at the farm, before loading. This proportion further increased to 80.7 after loading, and to 95 .8% after lair age. Some injuries were associated with management procedures, including the position of the animal inside the loading compartment and the duration of pre - slaughter fasting. In pigs there is a relationship between skin lesions and the increase in cortisol and creatinine phosphokinase concentrations (Warriss & Brown, 1985). Bruising may store historical information about the harmful situations that the animal underwent prior to slaughter. The farmer and the transport companies have economic incentives to prevent and reduce bruising. However, slaughterhouses do not have simple and accurate methods for post-mortem age estimation of bruises to assess accurately when bruises were sustained. This is a relevant problem, due to the importance of having to decide who is economically accountable for the losses (Strappini, Metz, Gallo & Kemp, 2009).

Conclusions

Considering that the current trend in intensive animal production systems is to increase transport time, the number of logistic stopovers and the incidence of mixed transport, it is necessary to develop tools and protocols that minimize the biological cost of adaptation to pre -slaughter handling. It is necessary to invest in improvements to preserve animal welfare and increase profits for the industry. Those improvements should be aimed at improving logistics to prioritize animal welfare, in addition to the promotion of legislation based on scientific evidence. The logistic process should be considered as a part of the agro-ecosystem management, emphasizing the transport variables under the constraints of animal welfare requirements. At the same time, it will be necessary to in- form consumers and convince the meat industry that the ethical value of a product is an element of growing economic importance and a business opportunity.

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