Preslaughter handling practices and their effects on animal welfare and pork quality[1]

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ABSTRACT: At all times, prior to slaughter, pigs may experience stress from a range of handling practices, such as fasting, loading and transport, mixing, and interaction with humans. These factors can affect the welfare of pigs and carcass and meat quality, both individually and collectively. Preslaughter stress is both an animal welfare and a meat quality issue. Behavioral and physiological studies have revealed that poor handling practices at the farm, during transport and at the slaughter plant, have an adverse effect on pigs and may result in the loss of profits due to animal losses during transport and in lairage. Also, poor preslaughter handling can also lead to losses in carcass value as a result of reduced yield, the presence of lesions and bacterial contamination, and meat quality defects (e.g., pale, soft, exudative and dark, firm, dry pork). These economic losses can be limited by improving the design of facilities, controlling the environmental conditions, and implementing training programs for the correct animal handling at any stage preslaughter. The objective of this review was to review research findings on the effects of preslaughter practices on ante-mortem behavioral and physiological response in pigs, including muscle metabolism, and to provide recommendations aimed at limiting the impact of preslaughter handling on animal losses and pork quality.

Key words: animal welfare, handling, meat quality, pigs, preslaughter

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INTRODUCTION

The day of slaughter consists of several stages, starting when pigs leave their pen and including transport, lairage, stunning, and exsanguination. At each stage, pigs are exposed to different stressors, including on-farm feed withdrawal, loading and transport, mixing, and human interventions and facility design (e.g., ramps, alleys, and docks), which both individually and(or) additively can contribute to animal losses and fatigued animals at slaughter (Ritter et al., 2009; Goumon and Faucitano, 2017). Preslaughter stress is also a carcass and meat quality issue as it may cause carcass depreciation due to severe skin lesions, weight losses, and meat quality defects due to abnormal postmortem muscle acidification (Faucitano, 2001, 2010; Schwartzkopf-Genswein et al., 2012). Responsibility for the occurrence of profit losses from farm to slaughter is equally shared by the producer and the abattoir. Firstly, the producer must guarantee proper genetic selection, care, and handling of pigs to the truck gate. Secondly, the abattoir is responsible for the optimization of lairage conditions (layout, ambient control, and handling systems) in order to maintain acceptable welfare conditions for pigs and ensure optimal, consistent, and uniform carcass and meat quality. Furthermore, responsibility for animal losses during transport may be either equally shared among the producer, trucker, and abattoir (in the case of

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integrated production systems) or shouldered alone by the trucker who can be fined up to $6,000 under Canadian Food Inspection Agency regulations for having three to four dead pigs in the truck load (Faucitano and Goumon, 2017).

The objective of this paper is to review the effects of on-farm conditions (i.e., housing system, feed withdrawal and handling), and conditions of transport (i.e., vehicle design) and lairage (i.e., duration and handling) on animal losses, pigs' physiological and behavioral response preslaughter and carcass and meat quality variation.

FARM OF ORIGIN

According to Grandin (1993), if the goal is to have quiet handling at slaughter, it is essential to bring easy-to-handle pigs to the harvest facility. This opinion reflects the effects of the farm of origin on the variation in behavioral and physiological response to preslaughter stressors and meat quality that have been reported in a number of studies (Brown et al., 1999; Dalla Costa et al., 2007; Dewey et al., 2009; Rocha et al., 2016). In an epidemiological study conducted in Canada, farm was identified as the major source (25%) of deads-on-arrival (**DOA**) and nonambulatory pigs on arrival at the plant compared with the transporter and the packer (16% each; Sunstrum et al., 2006; Dewey et al., 2009). The main sources of variation of these effects between farms include: the housing system (Barton-Gade, 2008; Rocha et al., 2016), the preparation of pigs for transport (Faucitano et al., 2010; Dalla Costa et al., 2016), and the handling of pigs at loading (Johnson et al., 2013; Goumon and Faucitano, 2017).

Housing System

Research has shown that when compared with pigs raised under intensive, barren, or with little environmental enrichment housing conditions, pigs raised in an enriched environment (lower stocking density, straw bedding, and more frequent contacts with humans) are easier to handle (Geverink et al., 1998; Tönepöhl et al., 2012) and fight less when mixed with unfamiliar conspecifics (De Jong et al., 2000; Terlouw et al., 2009; Tönepöhl et al., 2012). They also have lower salivary cortisol concentrations during transport than those raised under barren housing conditions (De Jong et al., 2000; Klont et al., 2001). Recently, Rocha et al. (2016) reported a greater percentage of panting on arrival at the slaughter plant and exsanguination blood lactate concentrations in pigs raised at conventional farms compared with pigs from an animal welfare-improved system. Pigs from conventional farms were also more reluctant to move at unloading, but this effect was biased by the handling skills of one of the two truckers in this study, which highlights the importance of handler training to ease pig handling (Dalmau et al., 2009; Fitzgerald et al., 2009).

Feed Withdrawal

Feed withdrawal is a recommended practice for on-farm preparation of pigs before slaughter in order to prevent animal losses and travel sickness during transport (Bradshaw et al., 1996; Averós et al., 2008; National Farm Animal Care Council, 2014), to reduce carcass contamination due to lower risk of gut contents spillage during carcass processing, and to improve pork quality (Faucitano et al., 2010). However, when compared with unfasted pigs, fasted groups of pigs (18 h prior to loading) appear to be more difficult to handle at loading, as they go backward, round-turn, and vocalize more (Dalla Costa et al., 2016). The increased frustration, fatigue, and excitement caused by hunger are the likely causes for these behaviors (Arnone and Dantzer, 1980; Lewis, 1999; Edwards et al., 2010b).

Based on a review of research findings, a fasting interval (from last feed to slaughter) of between 16 and 24 h has been proposed as an acceptable compromise between the welfare of animals during handling and transport and food safety and quality (Faucitano et al., 2010). However, under specific commercial conditions (i.e., split-marketing) this fasting interval is sometimes only applied during transport and lairage at the plant. The reason for this choice is the lack of shipping facilities where the heaviest pigs can be moved to ahead of time before loading (see later section) and have their feed withdrawn separately from the group of origin (Faucitano et al., 2010).Therefore, starting fasting time at the departure from the farm may still prevent the risk of full stomachs at slaughter, provided the 16 to 24 h fasting time is respected by imposing longer lairage time at the abattoir; however, it may reduce the welfare of pigs during transport and in lairage (Guàrdia et al., 1996; Warriss, 1996; Stewart et al., 2008). Keeping mixed groups of pigs in lairage for a long time (overnight to >24 h) has, in fact, been associated with an increased number of fights, due to hunger-related irritability and excitement (Warriss et al., 1998; Guàrdia et al., 2009;

Dalla Costa et al., 2016), greater risk of skin lesions on the carcass (Guàrdia et al., 2009), and pork with dark, firm, dry (**DFD**) characteristics (Dalla Costa et al., 2016).

Driving Pigs from the Pen to the Truck Gate

Moving pigs forward from the home pen to the truck gate is considered the most critical phase of the transport period as shown by an increase in heart rate (Correa et al., 2013, 2014) and in stress indicators (salivary cortisol and blood lactate; Bradshaw et al., 1996; Correa et al., 2010; Edwards et al., 2011) compared with the values from pigs at rest, with the effects of loading stress lasting until slaughter and eventually influencing meat quality variation (Correa et al., 2010; Edwards et al., 2011). The stress associated with the loading procedure results from a combination of different factors, such as group splitting in the finishing pen, group size, and handling system, among others.

Group Splitting

Group splitting, which is a practice applied to handle small groups of pigs (4 to 6 pigs/group; Lewis and McGlone, 2007) through the alleys at the time of loading, is the most stressful task a market pig must cope with during transport to slaughter due to the close human–animal interaction and the change in the animal's social environment caused by its separation from the group (Geverink et al., 1998). These stressors correspond to the physical stress of walking long distances (up to more than 100 m; Ritter et al., 2008a) to exit the barn and get to the truck gate. The cumulative effects of these events may result in an increased frequency of open-mouth breathing, skin discoloration, and elevated blood lactate concentrations and are indicators of animal fatigue, reported in pigs driven over a long distance (46 to 91 m) compared with those moved over a short one (15 to 24 m) to reach the loading area (Ritter et al., 2007, 2008a; Edwards et al., 2011). Given their proximity to the barn exit, the use of shipping rooms, to which pigs are moved to at least 2 to 4 h before loading, can help minimize the effects of exercise on the physical condition of pigs at loading (Chevillon, 2001). The practice of presorting groups of pigs in shipping pens has been shown to reduce pigs' response to handling stress (i.e., lower heart rate) and improved the ease of loading, resulting in shorter loading time (50 vs. 20 min for a batch of 100 pigs) and a 25% reduction in death losses during transport (Chevillon, 2001). More recently, reduced open-mouth breathing and skin discoloration during loading, resulting in a 66% decrease in total losses (DOAs and downers) on arrival at the abattoir, were reported in pigs presorted 24 h prior to loading (Johnson et al., 2010). However, Johnson et al. (2013) cautioned about the interpretation of these results as they may have been biased by the raising system (large vs. small groups) during the growing–finishing phase in this study. Pigs raised in larger pens tend to be faster to load (Hayne et al., 2009) because they are more fit and resistant to handling as they had more room to exercise during the growing–finishing period (Johnson et al., 2013; Rocha et al., 2016).

However, the use of shipping pens also implies the need to mix pigs originating from different pens (Goumon and Faucitano, 2017) and for this reason they represent one of the major sources of fighting-type lesions on the carcass (Brandt and Aaslying, 2015). Keeping pigs in small shipping pens or adjusting the stocking density according to the length of wait time before loading have been recommended to limit the fighting rate in this situation (SCAHAW, 2002; Weeks, 2008; Goumon and Faucitano, 2017).

Moving Tools

Under commercial conditions, common tools for moving pigs at loading are plastic paddles and boards, electric prods, and flags. These tools do not have the same efficiency and the same effects on pig behavior and physiology during handling (Faucitano and Goumon, 2017). The electric prod appears largely used on farm and on the truck to speed up the procedure of loading and reduce the workload of handlers through the alleys and ramps (Griot and Chevillon, 1997; Faucitano, 2001; Correa, 2011). However, regulations and codes of practice recommend to limit, if not avoid, the use of electric prods for pig handling at all stages of preslaughter (EC Directive, 1993; SCAHAW, 2002; National Farm Animal Care Council, 2014). In fact, this handling tool reduces the ease of handling (McGlone et al., 2004) due to increased backing-up, round turns, slipping, falling, and jamming (Rabaste et al., 2007; Correa et al., 2010; Edwards et al., 2010a; Dokmanovic et al., 2014) and produces a negative physiological response in terms of higher and greater heart rates and blood lactate concentrations (Correa et al., 2010; Edwards et al., 2010a). A greater incidence of nonambulatory pigs (Benjamin et al., 2001; Correa et al., 2010) and pale, soft, exudative (**PSE**) and blood-splashed pork has

been reported after the use of electric prods (van der Perre et al., 2010; Correa et al., 2010). In view of these requirements, most abattoirs have banned electric prods from their list of handling tools (Gentry et al., 2008; Correa, 2011). However, handlers are still allowed to use electric prods as a last resort when a fit animal refuses to move forward (Grandin, 2002), but cannot abuse them. Hitting a pig with an electric prod more than twice and for more than 1 s per hit during handling causes a negative physiological response, in terms of increased rectal temperature and blood lactate concentration (Ritter et al., 2008b).

In a search for alternative handling tools, McGlone et al. (2004) compared the efficiency and effects of flags, paddles, and plastic boards and concluded that the plastic board and the flag were the most efficient devices for moving pigs because they appear as solid, blocking walls. In another handling study using either plastic boards combined with a paddle or electric prod or a compressed air prod along the alley and the loading ramp, Correa et al. (2010) concluded that to improve animal welfare (i.e., lower exsanguination blood lactate) and reduce skin lesions on the carcass and blood splashes in pork meat, the electric prod should be replaced with paddles or compressed air prods.

TRANSPORTATION TO THE SLAUGHTER PLANT

Transportation is a multicomponent phenomenon starting with the entrance of animals into the vehicle through its gate and ending with their unloading at the slaughter plant. It consists of the effects of multiple factors, such as vehicle design, handling at loading and unloading, among others, which have a great impact on the welfare of pigs (Faucitano and Goumon, 2017).

Vehicle Design

The vehicle type for pig transportation to slaughter can vary widely, from single- or double-deck trucks (common in Europe and South America) to large three-deck punch-hole trailers, either "pot-belly" (**PB**) or straight/flat-deck models (commonly used in North America) due to their large load capacity, which allows to haul more than 200 pigs in one trip and for long distances (McGlone et al., 2014b; Faucitano and Goumon, 2017). Vehicle design features that may have an impact on the welfare of pigs during transport include the loading system (ramps or hydraulic device) and microclimate control (Faucitano and Goumon, 2017).

Within Truck Loading and Unloading Systems

A greater risk of DOAs and PSE pork has been reported in pigs being moved through fixed decks and ramps within the vehicle (Guàrdia et al., 2004; Barton-Gade et al., 2007). Pot-belly trailers are an example of vehicles featuring multiple (up to 5) and steep (up to 40° slope) internal ramps and 180° turns to load and unload pigs from the top and bottom fixed decks (Weschenfelder et al. 2012, 2013). The design of the PB trailer makes the procedures of loading and unloading more difficult as demonstrated by the increased use of electric prods and longer handling time inside the vehicle (Ritter et al., 2008a; Torrey et al., 2013a,b; Weschenfelder et al., 2013). This reduced ease of handling has been associated with a greater proportion of dead and fatigued pigs on arrival at the plant, and greater exsanguination blood cortisol, creatine kinase (**CK**), and lactate concentrations in comparative studies using other types of vehicle, equipped with hydraulic decks, such as a double-decked truck or a flat/straight-deck trailer (Ritter et al., 2008a; Sutherland et al., 2009; Kephart et al., 2010; Weschenfelder et al., 2012; Correa et al., 2013). Weschenfelder et al. (2013) also showed greater water exudation in the ham and loin muscles from Piétrain Hal^{Nn} crossbred pigs transported for a short time (45 min) using a PB trailer compared with a flat-deck trailer.

Microclimate Control Inside the Vehicle

Increased percentage of dead pigs and pigs showing open-mouth breathing on arrival at the processing plant have been reported at ambient temperatures above 17 and 20 °C, respectively (Sutherland et al., 2009; Kephart et al., 2010). Increased animal losses during transport are due to an internal trailer temperature increase that occurs at each degree of ambient temperature increase (Dewey et al., 2009). This internal temperature increase is greater in PB trailers than in flat-deck trailers, either while stationary or moving (Ritter et al., 2008a; Weschenfelder et al., 2012), due to the punch-type pattern openings on the sides of the pot-belly trailer which reduces the air flow through the compartments compared with the slatted openings of the flat-deck trailer (Weschenfelder et al., 2012). However, as pot-belly and flat-deck trailers are passively ventilated vehicles, stops (at loading, during the journey and before unloading at the

plant) are particularly detrimental for the quality of the internal ambient conditions of both vehicle types and are a significant source of pig losses (Haley et al., 2008a,b; Sutherland et al., 2009). In a stationary trailer, overall temperature can increase above 30 °C, with the bottom front compartments being up to 10 °C warmer than the external ambient temperature (Weschenfelder et al. 2012, 2013; Fox et al., 2014). The longer the stop, the greater the temperature increase inside the vehicle and the greater the risk of losing animals. After a 30-min stop some critical trailer compartments (middle and bottom front) can be 6 to 10 °C warmer than the external temperature (Weschenfelder et al., 2012; Fox et al., 2014). Under these thermal conditions, the risk of pigs dying in the truck can increase by 2.2 times with every 30-min increase in stop time (Haley et al., 2008a,b) reaching 0.28% DOA after a 4-h stop time at external temperatures above 20 °C (Sutherland et al., 2009).

Under these poor thermal conditions, pigs kept in a stationary trailer should be cooled-off by water sprinkling/misting or fan-assisted ventilation or the two systems combined (Brown et al., 2011). Water sprinkling/misting pigs using a hose or in-built water sprinklers/misters has been reported to be a useful practice to improve animal thermal conditions inside the trailer and reduce the risk of death during transport (up to 25% fewer DOAs; Colleu and Chevillon, 1999). The application of 5-min water sprinkling at the departure from the farm after loading and 5-min before unloading at the harvesting plant at ambient temperature above 23 °C has been shown to decrease pigs' body temperature, as assessed by gastrointestinal tract temperature monitors (iButtons), upon arrival at the plant and drinking behavior in lairage (Fox et al., 2014). When applied starting from an ambient temperature of 20 °C, water sprinkling reduced exsanguination blood lactate concentration (an indicator of fatigue) and improved meat quality (higher initial pH and lower drip loss in the loin muscle), particularly in pigs transported in the middle front and rear compartments (Nannoni et al., 2014). However, an increase in relative humidity (up to 7.5 %) has also been observed in a sprinkled trailer, which may prevent efficient evaporative cooling (Fox et al., 2014). To help remove the excessive humidity from the interior of a sprinkled truck that reduces pigs' body temperature by increasing evaporative cooling, water misting should be combined with fan-assisted ventilation (Christensen and Barton-Gade, 1999). Recently, the application of forced ventilation using external fan banks in combination with 10-min water misting appeared to improve thermal comfort (lower gastrointestinal tract temperature) and reduce dehydration (lower exsanguination blood hematocrit level) in pigs kept in a stationary truck during a 30-min wait before unloading at the slaughter plant (Pereira et al., 2016).

Transport losses have also been reported at low ambient temperatures (Clark, 1979; Guàrdia et al., 1996; Rademacher and Davies, 2005; Ellis and Ritter, 2006; Sutherland et al.; 2009). Probable causes of the greater rates of DOAs or nonambulatory pigs in winter compared with other seasons may be more difficult animal handling through the slippery (due to ice) internal ramps at loading and unloading (Torrey et al., 2013a,b) and insufficient bedding of the trailer floor resulting in more pigs standing during transport to avoid the contact with the cold aluminum floor surface (Goumon et al., 2013). The presence of slippery ramps has been shown to result in more slips and falls at loading and unloading, greater heart rates during transport and unloading, and increased blood CK and lactate concentrations at slaughter (Goumon et al., 2013; Correa et al., 2014). The contact with the cold floor surface of the trailer due to insufficient bedding has been associated with increased number of carcass lesions, including frostbites (Goumon et al., 2013; Scheeren et al., 2014).

To control the vehicle's internal environment and maintain the pigs' thermo-neutral zone in winter, vehicles must be fitted with boarding (i.e., proportion of the sidewalls of the vehicle closed by inserting boards or plugs, and insulating material). At temperatures between −12 and 9.4 °C vehicles must be fitted with 90% boarding to keep pig heat in the vehicle and reduce animal losses (NPB, 2014). Increased DOA have been reported in trucks fitted with a low boarding level (0 to 30%) at temperatures below 5 °C (McGlone et al., 2014a).

Lower temperatures have been recorded in the upper compartments of trailers and has been explained by the presence of more exposed surfaces and a lack of roof insulation both of which increase thermal radiation from the upper deck cooling these compartments (Brown et al., 2011; Weschenfelder et al., 2012). If cool temperatures may be beneficial for pigs transported in these trailer location under warm ambient conditions, they may be detrimental for their thermal comfort in winter. Adding a 5-cm layer of styrofoam insulation to the ceiling of the upper deck can increase the internal temperature by 10 °C under cold weather conditions (−20 °C; Gonyou and Brown, 2012).

Reception at the Abattoir

Based on its impact on the welfare of livestock at this stage, the truck's timeliness of arrival is a core criterion evaluated by numerical scoring in slaughterhouse audit protocols (Rocha et al., 2016; Grandin, 2017). The primary recommendation is to begin unloading the animals within 0.5 h of arrival at the slaughterhouse and complete it within an hour to avoid heat and humidity increase inside the stationary truck and its negative consequences on the welfare and meat quality of pigs (Driessen and Geers, 2001; Ritter et al., 2006; Haley et al., 2008a,b; van der Perre et al., 2010; Grandin, 2017). A strict coordination of truck arrivals with the predicted number of pigs in lairage, lairage capacity, and speed of operation as well as a number of unloading docks allowing more than one truck to unload at the same time may help shorten waiting times in abattoirs (Faucitano and Pedernera, 2016).

To avoid overlapping, slipping, jamming, vocalization, and round-turning at unloading, pigs should be unloaded by compartment rather than by deck and in small groups using paddles or boards only (Rabaste et al., 2007; Faucitano and Geverink, 2008). An increased noise level (≥85 dB) produced by pigs' vocalization at this stage can be conducive to a faster muscle pH drop rate and greater risk of PSE pork (van der Perre et al., 2010; Vermeulen et al., 2015b).

LAIRAGE CONDITIONS

Besides creating a reservoir of animals aimed at maintaining the constant speed of the slaughter line, the purpose of lairage is to give stressed/fatigued animals an opportunity to recover from the stress of transport and unloading (Faucitano, 2010; Gallo et al., 2016). Mistakes made at this stage should be avoided as they can prevent pigs from resting and recovering and offset all efforts made by the production sector to improve performance, animal welfare, and carcass and meat quality. The recovery rate of pigs in lairage and the related economic losses due to poor carcass and meat quality depend on lairage time, the quality of the handling systems, facility design, and environmental control (Faucitano, 2010; Gallo et al., 2016).

Lairage Duration

A 2 to 3 h lairage time is usually recommended to allow the pigs to recover their physiological condition (i.e., return of cortisol to the basal concentrations in blood) after transport and unloading and ensure the production of good quality pork (Warriss, 2003). Unless required by the adverse ambient conditions (e.g., >30 °C or >10 ppm ammonia; Fraqueza et al., 1998; Weeks, 2008), short lairage intervals (15 to 60 min) should not be applied as they may result in higher muscle temperature and muscle lactate concentration at slaughter resulting in an increased incidence of PSE pork (Fraqueza et al., 1998; Shen et al., 2006). However, although longer lairage time (overnight) helps reduce the risk of PSE pork by 2% (Guàrdia et al., 2005), it increases the risk of DFD pork by 19% (Guàrdia et al., 2005). The increase in the proportion of DFD pork with lairage time is the result of reduced muscle glycogen content at slaughter caused by the combined effect of fasting and fighting within mixed groups of pigs (Nanni Costa et al., 2002; Guàrdia et al., 2009; Dalla Costa et al., 2016). The fighting rate and subsequent skin lesion scores increase with lairage time (Warriss, 1996; Faucitano 2001, 2010). Guàrdia et al. (2009) reported an almost 2-fold greater risk of skin lesions in pigs kept in lairage for 15 h compared to 3 h (18 vs. 10%). The increased level of aggression over time can be explained by the effect of fasting on pigs' frustration and nervousness (Brown et al., 1999; Dalla Costa et al., 2016). The pigs' emotional state can be aggravated by the size of the group (groups of 10 pigs fighting 10 times less than groups of 30 pigs; Rabaste et al., 2007), stocking density (greater space allowance of 2.7 pig/m^2 or 0.85 m^2/pig resulting in more fighting; Moss, 1978; Geverink et al., 1996; Weeks, 2008), and sex (intact males or ractopamine-fed immunocastrates fighting more intensively and longer than surgical castrates; Warris and Brown, 1985; Rocha et al., 2013).

Moving Pigs to Stunning

The combination of faster slaughter speed, poorly designed handling systems, and large groups during the short period between the exit from the lairage pen and stunning may result in a greater proportion of slips, jamming, backing-up, and vocalization (Warriss et al., 1994; Edwards et al., 2010a, 2011; van der Perre et al., 2010; Vermeulen et al., 2015a; Rocha et al., 2016), and an increased use of electric prods (Rocha et al., 2016). These behavioral responses have been associated with a greater heart rate (Correa et al. 2010, 2013), exsanguination blood lactate and CK concentrations (Hambrecht et al., 2005; Edwards et al., 2010a; Rocha et al., 2015), skin lesions scores (Rabaste et al., 2007), and lower pH values at 24 h postmortem and

water-holding capacity in pork meat (van der Wal et al., 1999; Hambrecht et al., 2005; Rabaste et al., 2007; Dokmanović et al., 2014; Vermeulen et al., 2015a). Furthermore, slips and electric prod use in the stunning area have been shown to be closely related to a variation in pork exudation (r = 0.74 and r = 0.69, respectively; Rocha et al., 2016). Based on these results, slips, electric prod use and high-pitched vocalization can be used as criteria for animal welfare monitoring and meat quality control at the slaughter plant (WQ®, 2009; Rocha et al., 2016; Grandin, 2017).

SUMMARY AND CONCLUSIONS

This review discussed the effects of the stressors experienced by pigs during the preslaughter process (from farm to slaughter) on animal losses, pigs' physiological and behavioral response, and carcass and meat quality variation. The farm of origin influences the pigs' response to preslaughter stress and meat quality through the effects of alleys and loading dock design and the handling system. To ease loading and reduce the workload of loading crews, it is recommended that farms use shipping rooms and apply training programs for their handlers.

The use of truck models featuring hydraulic ramps or decks also proved to help reduce the workload of handlers and improve the welfare of pigs during transport. However, more research on truck design is needed with a study of the airflow patterns, vibration rate, and insulation and cooling systems under different ambient conditions where temperature control becomes more critical and physiological heat maintenance and dissipation in pigs becomes less effective.

Lairage and slaughter are extremely important for the pork-chain economy as mistakes made at these points have irreversible effects on carcass and meat quality and may offset all efforts made by the production sector to improve performance and animal welfare. Precautions must be taken to ensure adequate handling and environmental control to safeguard the benefits of lairage as a resting area enabling pigs to recover from the stress of transport and limit the effects of the slaughter procedure. The correct management of critical areas in lairage is becoming paramount in the light of the increasing need for commercial abattoirs to obtain audit approval and animal welfare certification for their meat products.

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