2011 AND 2012 EARLY CAREERS ACHIEVEMENT AWARDS:
Farm and pig factors affecting welfare during the marketing process[1,2]

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ABTSRACT: The objective of this paper is to review the scientific literature to identify on-farm factors that contribute to market weight pig transportation losses. Transportation of market weight pigs is an essential element to the multisite pork production model used in the United States. In 2011 alone, approximately 111 million market weight pigs were transported from the finishing site to the abattoir. For pigs, the marketing process can present a combination of potentially novel, physical, and/or unfamiliar experiences that can be stressful. If the pig cannot cope with these sequential and additive stressors, then an increased rate of transportation losses could occur with a detrimental effect on pork carcass value. Current yearly estimates for transport losses are 1 million pigs (1%). A variety of market weight pig and farm factors have been reported to detrimentally affect transportation losses. By understanding how pigs interact with their environment during marketing, researchers, producers, and personnel at the abattoir may begin to identify, prioritize, and attempt to minimize or eliminate these stressors. This process will ultimately decrease transportation losses, improve pork quality, and increase profitability.

Key words: handling, swine, transport, welfare

INTRODUCTION

Transportation is an essential element to the multisite pork production model currently used in the United States where farrowing, finishing, and processing occur in different locations. Locating different pork production phases some distance apart can reduce the exposure risk from catastrophic disease losses. In 2011 alone, approximately 111 million market weight (~130 kg) pigs were transported to the abattoir in the United States. Estimates reported in the literature indicate that approximately 1% of market weight pigs will be classified as "transport losses," so for 2011, this equated to 1.11 million pigs (S. Meyer, Paragon Economics, Des Moines, IA, personal communication).

The term "transport losses" refers to pigs that become nonambulatory, defined as a pig that is unable to keep up with its contemporaries and may have a structural injury or die at any stage of the marketing process (Ritter et al., 2009; Ritter et al., 2009b). Nonambulatory pigs with no injuries have also been labeled as "fatigued." Fatigued pigs display altered behavior and undergo metabolic changes. When the

2481

Table 1. On-farm factors that may affect the welfare of the finisher pig during the marketing process

Areas of the farm			
Pig	Facility and management	Caretaker	Pig–human interaction
Genetics	Diet interventions	Presorting[1]	Handling tools[1]
BW	Feed withdrawal	Experience[1]	Handling intensity[1]
Gender	Ractopamine	Attitudes[1]	Group size[1]
Degree of muscling[1]	Lighting and aisle width, flooring	Beliefs[1]	
Health status[1]	Pen design[1]	Personality[1]	
Fitness	Loading distance[1]		
	Loading ramps[1]		

[1]Items are discussed in this review.

pig begins to experience stress it displays open-mouth breathing, skin discoloration, or both. If the stress is not removed or if additional stressors are encountered, the pig will become reluctant to move, make abnormal vocalizations, develop muscle tremors, or display some combination of stress indicators. At this stage, the pig may become overwhelmed by the accumulation of stressors, in which case the pig will collapse and become nonambulatory and, in severe cases, death may ensue (Ritter et al., 2009b). Metabolically, these pigs are experiencing acidosis characterized by high blood lactate and low blood pH values (Anderson et al., 2002; Ivers et al., 2002). Chronic stress depletes muscle glycogen stores and may result in physical exhaustion and fatigue (Gregory, 1994, 1996). More recent work supports this theory. Carr et al. (2005) reported that the majority of fatigued pigs evaluated had high ultimate loin muscle pH (5.90 to 7.00), suggesting that muscle glycogen stores were substantially reduced before slaughter.

Transport losses represent 3 challenges for the U.S. swine industry. First, it is an animal welfare concern; for example, nonambulatory pigs cannot walk and in turn may be stepped on by their contemporaries. Second is the potential for increased United States Federal government oversight, for example, the Downed Animal and Food Safety Protection Act, Bill H. R. 661 (U.S. House of Representatives, 2007) and Bill S. 394 (U.S. Senate, 2007). If this bill had passed both the House and the Senate, any animal that became nonambulatory would have been immediately humanely euthanized and would not have been allowed into the human food chain. The third challenge is direct financial losses to producers and packers due to additional time to handle fatigued pigs, carcass condemnation, and trim loss associated with injured and dead pigs (Ellis et al., 2003; Ritter et al., 2009b). The National Pork Board (Des Moines, IA) has ranked pig welfare during handling and transportation as 1 of their top research priorities over the past decade. In addition, the pork industry has made attempts to reduce transportation losses during the marketing process, through handling and training materials and updating

educational materials such as the Trucker Quality Assurance Program (TQA, 2008; NPB, 2012).

TRANSPORTATION EVENTS DURING THE LIFESPAN OF THE MARKET PIG

Typically, the newly weaned pig is transported from sow farms at about 3 wk of age to a confinement facility, commonly referred to as a nursery–grow–finish or wean–finish building, where they remain until marketing at approximately 6.5 mo of age (81% of pigs; USDA-APHIS-VS, 2006). The heating and ventilation in these facilities is electronically controlled to maintain optimum temperature and air flow for the pigs across many weight phases occurring during the life of the pig from the time it is weaned (~5 kg) until it reaches market weight (105 to 118 kg). Pigs are provided ad libitum access to water and fed in a ration that meets their nutritional requirements for their age and stage of growth (NRC, 2012). The majority of pigs are kept on fully slatted concrete flooring (74.5%; USDA-APHIS-VS, 2006), and the recommended space allowance ranges from 0.56 to 0.74 m^2 per pig. Usually these pigs do not leave their pens until they are marketed and as a result have limited changes to their environment during rearing.

Unfamiliarity of the Marketing Process and Pig Senses

The marketing process has been defined as movement from the home pen to the abattoir (Ritter et al., 2009b). This process involves a combination of potentially novel (defined as the first exposure), unfamiliar (defined as more than 1 exposure but the exposure is infrequent in nature), and physically exerting experiences that could be perceived as stressful (Table 1). For example, Lewis et al. (2008) demonstrated that a ramp and typical handling experiences are not stressful for pigs, except when experiences are novel. Pigs process novelty and unfamiliarity through their senses. Pigs have a very acute sense of smell (Houpt, 1998) and are sensitive to temperature (Heffner and Heffner, 1990). Pigs have color vision and a panoramic range of about 310° and binocular

vision of 35 to 50°. The extent to which pigs have color vision is still a source of some debate. However, the presence of rods and cones with 2 distinct wavelength sensitivities in the blue and green frequencies suggests that at least some color vision is present (Lomas et al., 1998). Their range for sound detection is from 40 Hz to 40 kHz (Heffner and Heffner, 1990); hearing is also well developed and localization of sounds is made by moving the head. Talling et al. (1996, 1998) reviewed uniform and intermediate sounds found at a farm, during transport, and at a packing plant. Results from those studies support 2 hypotheses about the perception of sound by the pig. First, pigs habituate to specific, loud, unfamiliar, mechanical sounds and second, avoidance is greater and habituation takes longer for intermittent sounds that increase in volume quickly than constant sounds that increase in volume slowly. In addition, the authors noted a large individual variation in their strength of aversion to sound.

Olfactory signals are likely to contribute to the stress and amelioration of stress in transported pigs. Pigs experience novel smells during transport that may be disturbing (Vieuille-Thomas and Signoret, 1992). One study examined the use of a putative stress-reducing pheromone to reduce the stress and losses from transport (Lewis et al., 2010). Trailers were randomly treated with 500 mL of maternal pheromone (**MP**) or isopropyl alcohol as the control. The rate of fatigued pigs coming off the truck was 0.41% for control pigs and 0.15% for MP-treated pigs. The MP treatment tended to reduce the rate of fatigued pigs 63% (although not statistically significant) but it also increased handling difficulty.

Additive Stressors

Stressors that impinge on a pig may vary in time, intensity, mode, and degree of novelty (Coleman et al., 1998). The pig has developed mechanisms to deal with both acute and chronic stressors. The "additive stressor model" was proposed by Broom and Johnson (1993). This model proposed that is an animal was subjected to multiple stressors within a short period of time, coupled with insufficient recovery between applications of subsequent stressors, the pig may not be able to maintain homeostasis. In the most severe cases, the pig may become nonambulatory-noninjured (fatigued), nonambulatory-injured, or even die (Ellis et al., 2003; Fitzgerald et al., 2009). Ritter et al. (2009a) studied the additive effects of handling intensity, transport floor space, and distance moved during handling and applied these potential stressors in a simulated transportation process. The authors reported that as the number of stressors applied to the pig increased, rectal temperature, blood lactate, and loin muscle lactate increased linearly and blood pH, bicarbonate, and base excess decreased linearly. These findings are of interest because Ivers et al. (2002) measured metabolic variables in pigs at the time of marketing and reported that fatigued pigs were in a metabolic state of acidosis. Therefore, removing just 1 stressor during the marketing process could decrease these signs of stress and improve the welfare of the pig overall.

PIG FACTORS THAT AFFECT WELFARE DURING THE MARKETING PROCESS

Degree of Muscling

The quest of commercial pork producers for decreased fat content and increased muscling in purchased seedstock is a result of larger abattoir premiums for lean, heavily muscled pigs and consumer demand for lean pork products (Stalder et al., 1998). Pigs that have been intensively selected for rapid lean growth rate have an increased percentage of large, fast-twitch, glycolytic, white muscle fibers (type IIB), which makes them potentially more susceptible to alterations in muscle metabolism (Depreux et al., 2000; Oksbjerg et al., 2000; Lonergan et al., 2001).

Depreux et al. (2000) identified all 4 myosin heavy chain isoforms present in the LM from market weight swine positive or negative for porcine stress syndrome (**PSS**; i.e., possessing the halothane gene). Swine with the PSS mutation underwent a type II shift where there was a pronounced increase in type IIB fibers at the expense of other fiber types. The increased reliance on glycolysis for ATP production, particularly within halothane sensitive animals, could potentiate the metabolic effects of increased sympathetic tone driven by stressors. Glycolytic products, accumulation of lactate, and lowered pH as well as other metabolic products contribute to fatigue and impaired muscle function. Moreover, the poor ability of the pig to dissipate heat could further compound the potential metabolic crisis.

If these physiological responses are continued past the biological capabilities of the individual pig, the pig will become nonambulatory as the system attempts to recover or, as suggested by Lambert et al. (2005), a reduction in workload or exercise cessation must occur. Related to the degree of muscling is the quality and health of the muscle itself. Recently, a particular genetic line was identified that suffered transport losses 5-fold over the industry average. Genetic testing identified a SNP in the dystrophin gene that was associated with this phenotype. Furthermore, a stress test induced with the inhalation anesthetic isoflurane resulted in a much greater number of deaths in affected animals compared with unaffected pigs. Echocardiography performed at the time of the test indicated that affected

animals likely died of a fatal arrhythmia that was associated with the novel SNP.

Health Status

The health status of pigs is believed to contribute to the rate of fatigued and dead pigs during marketing. Clark (1979) performed necropsies on 336 randomly selected market weight pigs from a total of 3,500, which were dead on arrival (**DOA**) over a 22-mo period in Canada. The authors reported severe and diffuse pulmonary congestion and edema in 235 (70%) of the dead pigs. Forty-eight (i.e., 13%) of the dead pigs evaluated had a variety of acute to chronic lesions in addition to pulmonary congestion and edema. The remaining 62 dead pigs evaluated (17%) had no lesions or acute to chronic lesions but no pulmonary congestion in addition to pulmonary congestion and edema. The remaining 62 dead pigs evaluated (17%) had no lesions or acute to chronic lesions, but no pulmonary congestion and edema evident. More recently, MacGregor and Dewey (2003) conducted gross examinations on all pigs that arrived dead at the abattoir over a 12-mo period. All pigs had cardiac muscle petechial hemorrhage and generalized respiratory tract hyperemia. They reported that 80% of the pigs that died during transport had darker, red-colored lungs, of which 20% were determined to have chronic enzootic pneumonia. Previous studies have examined the changes in the myocardium (Johannsen and Menger, 1978; Johannsen and Kunz, 1980) and morphology (Greve, 1974; Berg and Pehlemann, 1988) from the hearts of pigs dying during transport. Johannsen (1979) reported the presence of hypoxemic myocardial lesions from dead pigs, which are suggestive of acute shock-type circulatory failure in pigs that died during transport. Bergmann (1978) suggested a myocardium involvement in the pathogenesis from pigs dying during transport. Carr et al. (2005) evaluated the lungs from 246 fatigued pigs and concluded that the lungs appeared normal. Likewise, Sutherland et al. (2008) evaluated feet and hoof scores, blood chemistry, virus profiles, and internal organ pathology from normal and fatigued pigs at a packing plant and failed to show an association between health status and fatigued pig incidence. Therefore, additional research is necessary to understand the relationship between pig health and market weight pig transport losses.

PIG–HUMAN INTERACTIONS THAT AFFECT WELFARE DURING THE MARKETING PROCESS

Caretaker–Pig Interactions

Good animal handlers who understand pig behavior, the production system, and their impact on stress levels experienced by the pig can minimize the impact of poor facility design. However, the best facility design and husbandry regimen can be rendered inadequate by poor animal handling. Stockmanship skills and animal handling basics have been well defined in the swine industry, but it is becoming apparent that continual training and performance monitoring are necessary to maintain continued success at a high level with minimal transport losses (Hill et al., 2007a). It seems likely that the knowledge and expertise of a caretaker as well as the personality, attitude, and beliefs of a caretaker about pig welfare will have a large impact on pig–handler interactions.

Caretaker Knowledge and Expertise. To be successful, a caretaker should acquire basic knowledge of the biology of the species with which he or she is working. This includes aspects of the behavior of the animal that helps the caretaker understand not only the interactions of the pig with its pen mates but also the interactions of the pig with the caretaker during routine husbandry tasks, such as handling. The primary objective of an animal handler is to minimize the level of fear of the animals and therefore their stress by maximizing positive interactions and encouraging the animals to move to the target location. This is accomplished by understanding the point of balance of the animals and how to manipulate the edge of the flight zone. Although initial interactions between caretaker and pig will be influenced by the preformed attitude of the caretaker toward pigs, subsequent interactions may vary and be reinforced as the caretaker gains experience. Unfortunately, this modification can be in the positive or negative direction, and therefore it is imperative that formal training also addresses the attitude and beliefs of the caretaker.

Caretaker Personality, Attitude, and Beliefs. Personality, attitudes, and beliefs are psychological concepts that influence human behavior and, thus, they all impact the way the caretaker interacts with the pigs under his or her care. Personality is a unique system of traits that affect how a person interacts with his or her environment and is relatively stable over time. The personality of a caretaker will impact the way he or she interacts with the pigs. Seabrook (1995) found that the personality profile for caretakers shown to exert high empathetic interaction, defined by a high degree of pleasant handling, vocal contact, and regular interaction at close quarters, was most frequently scored as being confident and self-sufficient. Other important attributes included being emotionally stable, conscientious, relaxed, practical, and humble. Caretakers with personalities that show a greater likelihood to be nonaggressive have decreased mortality within their herds and increased numbers of piglets reared per sow (Seabrook and Darroch, 1990). Ravel et al. (1996) also

found positive correlations between sow performance and personality scores representing warmth, emotional stability, and self-discipline.

Although caretaker personality certainly does impact the human–pig interaction, the strongest predictors of caretaker behavior have been found to be beliefs and attitude (Broom and Johnson, 1993; Hemsworth et al., 1994; Coleman et al., 1998). Beliefs are assumptions or convictions that are held to be true. Attitudes are learned, object related, and changeable by new information or experiences (Ajzen, 1988). Thus, unlike personality traits, attitudes and beliefs are relatively malleable. Putting the theories of Ajzen and Fishbein (2005) of reasoned action and planned behavior very simply, the behavior of the caretaker toward the pigs is immediately preceded by the intention to carry out that behavior, which in turn is determined by the attitude toward the behavior. The attitude toward the behavior is shaped by beliefs about the behavior influenced by background factors, which include such things as personality, intelligence, education, culture, age, gender, etc., but also, importantly, the knowledge of the caretaker. Therefore, by increasing the knowledge base of the caretaker, beliefs and attitudes can be changed and the end-point behavior impacted.

A group based in Australia has done extensive work on the role and empathy of the caretaker in relation to pig fear and its effects on performance. Early studies demonstrated relationships between caretaker behavior and fear and reproductive performance in pigs (e.g., Gonyou et al., 1986; Hemsworth et al., 1989). Subsequent studies have investigated methods to influence caretaker beliefs and attitudes using cognitive behavioral modification. In 1 study on small individually operated farms, Hemsworth et al. (1994) compared a no-training treatment (control group; 12 farms) with an intervention treatment (modification group; 13 farms) that consisted of a 1-h individual education and discussion session with the caretaker designed to improve knowledge of handling and beliefs about pigs, thereby influencing the attitude of the caretaker and subsequent behavior toward pigs. Results indicated that after intervention training, there were significant improvements in the positive attitude toward animals and in behavior of the caretaker toward pigs, the behavioral response of pigs to humans, and a trend toward improvement in pig reproductive performance. No such improvements were observed in the control treatment. A similar study performed on a single, large-scale operation found broadly similar results, with the intervention treatment also working to improve beliefs about pigs, decrease negative behaviors directed at the pigs, and improve measures of human–animal relationship (Coleman et al., 2000).

There was also a tendency for the modification program to improve staff retention.

Caretaker Situational Variables. Coleman et al. (2000) emphasized the fact that on a large-scale operation, caretakers are more susceptible to peer pressure from workmates and pressure from managers that may act to "dampen" the benefits seen by the modification intervention. This is an example of a situational variable. Positive attitudes toward pigs may well be challenged and altered by other caretakers, and this especially happens when new caretakers enter an environment where the manager or coworkers have a negative attitude already in place (Seabrook, 2001). Other situational variables may include such things as workload, time constraints, and personal or environmental issues that may impact caretaker mood. High caretaker workload has been inferred to negatively impact the amount of positive human–animal interactions (Lensink et al., 2000) and time pressure is mentioned by caretakers as a reason for aversive actions (Seabrook, 2001). Personal issues may include feelings of stress, unhappiness at home, and clashes with coworkers. The work environment may also impact caretaker behavior adversely, for example, if the building is overly hot or dusty or has poor air quality.

Previous Handling

In most commercial settings, pigs may have little to no direct contact with humans and typically do not leave their home pen until they are marketed. As a result, it has been recommended that caretakers walk home pens and routinely handle pigs to minimize stress responses during the loading and marketing process (Grandin, 1997; Geverink et al., 1998b). Although there have been no published studies reporting a decrease in transport losses resulting from caretakers walking the pens during the grow–finish period, it is interesting to note that Abbott et al. (1997) reported that pigs routinely handled and moved required less time to leave their home pens during the loading process than pigs that had not been previously moved (16 vs. 82 s). Likewise, Geverink et al. (1998b) reported that market weight pigs that were routinely loaded into a transport box and transported for 2 min required 50% less time during loading than control pigs or pigs that were routinely handled within the pen. Stewart et al. (2008) evaluated the effects of previous handling effects (i.e., moving pigs out their home pen to the load-out area on the day before loading) on transport losses. The authors reported that previous handling reduced stress indicators (i.e., open mouth breathing and skin discoloration) during loading and tended to reduce total transport losses compared with pigs that were not previously handled (0.07 vs. 0.38%, respectively).

Handling Tools

Many tools are currently used to effectively sort and move market weight pigs from a pen to the trailer. The most common handling aids recommended by the swine industry to move finisher pigs include plastic boards, large flags, or plastic paddle sticks (NPB, 2012). The use of electric prods, also called "hot shots," is controversial across the pork production chain (Warriss and Brown, 1994; Grandin, 2002). The Pork Quality Assurance Plus program literature notes that the use of electric prods is a stressful event and should be avoided or absolutely minimized (NPB, 2012). Research on the level of electric prod use and implications to the pig is sporadic. Veum et al. (1979) indicated that stress susceptible pigs have a greater physiological response to the effects of the prod. Guise and Penny (1989) found that the incidence of skin blemish in pigs had a significant interaction with the use of prods and stocking density during transport. McGlone et al. (2004) compared an electric prod with a paddle that had a plastic handle and a plastic board on how effective they were to move finisher pigs. They reported that pigs moved with a board had decreased (~80 s total time) moving time compared with pigs handled with electric prods (~120 s) or paddles (~130 s). Küchenmeister et al. (2005) compared the impact of different kinds of stress (nose snare and electric prod) just before slaughter on meat quality. Heart rate (**HR**) of the control animals (i.e., no additional stress) increased slowly during the gentle movement (i.e., starting about 5 min before slaughter) from the lairage box to the stunning pen from about 100 to 175 beats/min (**bpm**). The nose snare stress started 5 min before slaughter after gently moving the pig into the stunning pen (with increasing HR comparable to the control animals). The HR decreased in the time course of snare use down to 100 bpm although the pigs were shrieking and pulling. The use of the electric prod not only increased the HR in a short time interval up to 200 bpm, but also the pigs were running to avoid the electrical shock. These different levels of stress are reflected in the meat quality and biochemical variables. There were generally no differences between control and nose-snared pigs. However, the use of the electric prod resulted in lower pH values immediately after slaughter (6.36 at 0 min) and at 45 min postmortem (5.42) compared with control (6.73 at 0 min postmortem and 6.28 at 45 min postmortem) and snared pigs (6.67 at 0 min postmortem and 6.24 at 45 postmortem). Color of the meat was also compared. Minolta lightness (L*) score is produced by measuring light reflection from the surface of meat. Minolta L* scores of 42 to 46 are preferred. The Minolta *L** values were increased in the electric prod group (53.7 vs. 49.9 for control and 53.7 for snared). Drip loss was approximately 2% greater in the electric prod group compared with control and nose snare pigs, but the difference between control and electric prod drip loss samples did not attain statistical significance. The results indicate an increased energy consumption and glycolysis postmortem by the application of the electrical prod.

Handling Intensity

Benjamin et al. (2001) evaluated handling intensity effects by moving pigs either "aggressively" or "gently." Moving pigs "aggressively" meant that handlers moved pigs through a 300 m handling course and up a ramp with frequent use of an electric prod. Moving pigs "gently" was defined as moving pigs through the same course, but pigs were moved up a ramp, moved at a moderate pace and a plastic cane was used to aid movement in place of an electric prod. Pigs moved aggressively had greater blood lactate and glucose but lower blood pH, bicarbonate, and base excess immediately after handling when compared with pigs moved at their own pace with livestock cane. Furthermore, pigs moved with electric prods may require more time to recover than pigs moved with livestock paddles, as pigs moved with electric prods had greater blood lactate and less blood bicarbonate and base-excess values 2 h after handling (Hamilton et al., 2004). Collectively, these studies demonstrate the adverse effects of moving pigs rapidly when caretakers use electric prods on blood acid–base status and the incidence of nonambulatory pigs.

Group Size during Movement from the Home Pen to Trailer

Berry et al. (2009) demonstrated that pigs moved in small groups ($n = 4$) had less open-mouth breathing (8.2 vs. 18.6%), skin discoloration (6.7 vs. 15.0%), and muscle tremors (0.1 vs. 0.6%) during loading and less open-mouth breathing (2.8 vs. 4.6%) and skin discoloration (0.4 vs. 0.9%) at unloading compared with pigs moved in large groups ($n = 8$). Furthermore, pigs loaded in small groups had lesser percentage DOA (0.19 vs. 0.56%) and fewer nonambulatory pigs (0.36 vs. 0.7%) at a plant resulting in fewer total losses (0.55 vs. 1.26%) when compared with pigs loaded in large groups.

FARM FACTORS THAT AFFECT WELFARE DURING THE MARKETING PROCESS

Facility Design

Pen Size. In recent years, wean-to-finish facility design has shifted from housing pigs in smaller groups to larger groups of 100 to 1,000 pigs/pen (Street and Gonyou, 2008). Conflicting reports are available that

outline both positive and negative aspects of large groups in terms of productivity and welfare. Whittington and Schneider (2004) report that large pens allow for pigs to choose an appropriate climate zone within the large pen and increase the abilities of the pigs to avoid more aggressive pigs. Additionally, large pens may provide benefits to the producer, such as reduced building costs due to less gating in the large pen designs.

Auto-sort technologies offer producers potential advantages over conventional grow–finish buildings in regards to minimizing stress on pigs during loading and transportation. In contrast to conventional finishing buildings that often offer pigs limited exercise and changes to their environment, auto-sort barns use large group sizes (~500 pigs), allowing pigs to move freely throughout the building. Auto-sort systems can weigh pigs daily before entering food courts, identify market weight pigs, and sort these pigs into a loading pen by the barn exit before loading. Potentially, auto-sort systems may reduce transport losses because pigs are not sorted from pen mates during loading, not moved long loading distances, and not mixed with unfamiliar cohorts during transport. Recent survey data indicated that auto-sort systems may reduce transport losses (Brumsted, 2004; Rademacher and Davies, 2005). Rademacher (2007) compared pigs raised in pens with auto-sort systems of 500 pigs/pen to pigs raised in conventional grow–finish housing with 35 pigs/pen. At the time of marketing, pigs from the conventional pens were 4 times more likely (0.29 vs. 0.07%) to have a fatigued pig and 5 times more likely (0.45 vs. 0.09%) to have pigs DOA than those coming from buildings with auto-sorting technology. It needs to be determined, however, if the reduction in losses is due to presorting pigs before loading, reduced loading distances, and/or not mixing unfamiliar pigs during transport. Despite the potential reduction for dead and nonambulatory pigs, many pork producers have expressed frustration with auto-sort systems due to the learning curve of the software, the time required to train the pigs, the upkeep of the system, difficulties associated with identifying and treating sick pigs, and potentially negative effects on growth performance traits (Gonyou and Whittington, 2006; Rademacher, 2007).

Presorting. Pigs often reach their targeted market weight at different times. Therefore, producers will often send several groups of pigs to market. To facilitate this, pigs that have reached targeted market weight will be identified and moved into a new pen to facilitate movement to the truck. Pigs will have access to water during this time period but often will have feed withheld. Presorting enables producers to restrict the access of the pig to feed, which in turn reduces vomiting incidences on the truck (Bradshaw et al., 1996) and potential carcass contamination if the gastrointestinal tracts are cut open during slaughter (Murray et al., 2001). Johnson et al. (2010) compared the effects of 2 different facility designs on stress responses (during loading and unloading) and transport losses at a packing plant. The new design had 192 pigs/pen and internal swing gates that were used to manually presort market weight pigs on the day before loading. The traditional design had 32 pigs/pen and pigs were not presorted before loading. Pigs from the new design had fewer DOA (0.01 vs. 0.23%), nonambulatory pigs (0.29 vs. 0.66%), and total transport losses (0.30 vs. 0.89%) at the abattoir compared with traditional pigs. However, it was difficult to ascertain if the reduction in transport losses was due to larger group size or the implementation of presorting. Gesing et al. (2010a,b) performed 2 studies to determine the extent to which group size and presorting impacted transport losses. Gesing et al. (2010a) reported that transport loss rates were similar between pigs raised in small (36 pigs/pen) or large (324 pigs/pen) pens throughout the grow–finish stage (0.34 vs. 0.31%, respectively). Similarly, presorting pigs did not prevent transport losses or decrease the fatigued (0.1%) or injured percentage (0.3%) of pigs (Gesing et al., 2010b).

Loading Distance

Ritter et al. (2007) evaluated effects of distance moved during loading on transport losses. Pigs were either moved a short distance (i.e., 0 to 30.5 m) or a long distance (i.e., 60.0 to 91.4 m) from a pen to a building exit. Moving pigs long distances compared with short distances during loading increased the incidence of open-mouth breathing after loading (24.9 vs. $11.0 \pm 1.03\%$, respectively) and tended to increase the incidence of nonambulatory pigs during loading (0.32 vs. $0.08 \pm 0.09\%$, respectively) and of nonambulatory, injured pigs at the plant (0.24 vs. $0.04 \pm 0.07\%$, respectively). However, distance moved did not affect other losses at the packing plant.

Loading Chute

Gonyou (1993, p. 11-22) reported that "animal movement is accomplished by making the target location, or route to it, more attractive than the starting location." Pigs are motivated to move by many factors including natural curiosity, odors, sounds, co-specifics, food, and fear (McGlone et al., 2004). Loading has the potential to be a stressful event for pigs due to the physical exertion, noise, and the effects of close contact with humans (Geverink et al., 1996). In comparison with other stressors (e.g., light changes, descending chutes, electric prod use) ascending the loading chute has been cited as the primary stressor, increasing HR to an

average of 165% above baseline levels (van Putten and Elshoff, 1978; Geverink et al., 1998a). Hill et al. (2007a, b) identified load-out system design requirements to minimize stress during loading for the market weight pig. These requirements included that 1) all facilities and handling equipment must be designed based on the behavioral and physiological attributes of the pigs, 2) design must provide a continuous unidirectional flow of pigs from the pen of origin to a target location, and 3) design must be compatible with site design, facility structure, and transport system. To facilitate these design requirements, key components include flooring profile and texture and slope of the loading chute (Berry et al., 2012).

It is difficult and dangerous to handle an animal on a slippery surface with poor traction (Grandin, 1997). The locomotion of a pig changes when it tries to walk on slippery surfaces. Changes include reducing speed and stride length and increasing stride time (Thorup et al., 2007). Currently, to overcome animal slippage due to bad design and the use of poorly selected flooring material, cleats are used with the intention of providing support to the hooves as the pigs move up and along the loading chutes. This, unfortunately, still allows for the loss of footing between cleats and, under certain circumstances, can result in injury to the dew claws.

The ascending chute angle impacts loading time and the stress on the animal. Van Putten and Elshof (1978) noted that as chute angle increased (i.e., 15, 20, 25, and 30°), HR increased linearly from 139% of baseline values to 202%. Furthermore, pigs refused to enter a chute of greater than 30°, which could be a function of the effort required of the pigs rather than the stress associated with a chute climb that is this steep. In agreement with that study, Warriss et al. (1991) evaluated chutes at 0, 10, 20, 25, 30, 40, 45, and 50° and reported that chute angle was critical in determining the time needed by the pigs to pass through the chute. However, passage time on slopes from 0 to 20° was similar and although there was a linear relationship between chute angle and passage time above a 20° slope, there was an interaction between chute angle and cleat spacing such that appropriate cleat spacing compensated for the effects a greater slope over 35°. Time required to ascend the 35° slope with 150 mm-spaced cleats was equivalent to the 20° slope with either 150 or 300 mm spaced cleats whereas 35°-sloped chutes with 300 mm spaced cleats required a greater time to ascend. It is worth mentioning that loading and unloading chutes can be avoided entirely by using modular containers or trucks equipped with hydraulic lifts (Brown et al., 2005).

Berry et al. (2012) compared 2 loading system designs on performance and welfare parameters for finisher pigs at the time of marketing. The first design was a traditional metal covered chute that offered a 19° angle to the bottom deck of a trailer, with the internal ramp of the trailer being used to access the upper deck. The second design was a prototype loading gantry that was covered, had flooring covered with epoxy to mimic cement flooring, and had a hydraulic lift that could be raised to the bottom deck (i.e., 7° angle) or top deck (i.e., 18° angle) of a trailer. Pigs loaded on the prototype loading gantry experienced fewer electric prods, slips, falls, vocalizations, and pile ups but there were no differences in total transport losses (1.5 pigs/load for traditional loading vs. 1.1 pigs/load for prototype loading). Therefore, this study demonstrated that loading systems could be designed to improve on-farm swine welfare at loading although these effects did not seem to improve total transport losses at the plant.

SUMMARY AND CONCLUSIONS

This review discussed the potential stressors of the marketing process at the farm level related to market weight pig transport losses. By understanding how the pig interacts with its environment and handlers during marketing, we may begin to identify, prioritize, and attempt to minimize or eliminate stressors with the ultimate aim of reducing transportation losses. Based on evidence presented in this review and without regard to what is practical or possible at most locations, the ideal system would consider all aspects of the growth and marketing process that affects the pig. The caretakers working with the animals should be trained and competent in husbandry skills and receive ongoing and meaningful training related to their job requirements. Caretaker–pig interactions should always occur in a positive and nonstressful way. During the growth phase, having healthy pigs fed to nutrient requirement and being structurally sound is vital. At the time of marketing, pigs should be moved in small groups from the pen to the loading chute. The main driving aid should not be the electric prod but rather a combinational use of sort boards, flags, or rattles. To accommodate the reduction in electric prod use, grow–finisher buildings should be built to facilitate the movement of the pig from the home pen to the trailer. Such considerations include the correct aisle width, lighting that does not cause dark or intense bright spots, and flooring that gives traction to the pig. Finally but also of extreme importance is the chute design, often an overlooked component. A chute that allows 2 pigs at a time to walk together, soft but consistent lighting, flooring that mimics concrete, lack of wind or sun in the face of the pigs, and minimal slope will all result in pigs loading smoothly, quietly, and with reduced stress. Deviations from these recommendations will introduce stressors that are additive and, if of

sufficient magnitude, duration, and intensity, could contribute to transport losses.

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