PIG HANDLING AND TRANSPORTATION STRATEGIES UTILIZED UNDER U.S. COMMERCIAL CONDITIONS

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ABSTRACT
The percentage of dead and non-ambulatory pigs at the packing plant averaged across 23 U.S. commercial field trials were 0.25% for dead and 0.44% for non-ambulatory pigs, and these losses have been estimated to cost the U.S. swine industry approximately $46 million annually. There are two types of non-ambulatory pigs observed under U.S. commercial conditions: fatigued (non-ambulatory, non-injured) and injured. The vast majority of non-ambulatory pigs are classified as fatigued. Fatigued pigs display signs of acute stress (open-mouth breathing, skin discoloration, and/or muscle tremors) and are in a metabolic state of acidosis characterized by low blood pH and high blood lactate values. Transport losses (dead and non-ambulatory pigs) at the packing plant are a multi-factorial problem consisting of people, pig, facility design, transportation, packing plant, and environmental factors. Although few studies have been conducted to determine the causes of dead and non-ambulatory pigs, it is well established that transport losses are increased by the HAL-1843 mutation, aggressive handling with electric prods, crowding pigs during transport, and extreme weather conditions. Management strategies to reduce transport losses under U.S. commercial conditions include better preparing pigs for transport, improving facility designs, minimizing stress during handling, and optimizing transport conditions.

INTRODUCTION
Transport losses at the packing plant represent animal welfare, regulatory, and economic concerns to the U.S. swine industry. First of all, improving the well-being of pigs during transport and reducing the incidence of dead and non-ambulatory pigs are animal welfare priorities. Secondly, non-ambulatory livestock are the subject of increased rules and regulations. For example, U.S. Department of Agriculture (USDA) inspectors and plant welfare auditors evaluate how non-ambulatory pigs are handled at the packing plant. Improper handling of non-ambulatory pigs at the plant can result in a USDA non-compliance report and/or a failed plant welfare audit. Thirdly, transport losses represent direct financial losses to pork producers and packers, and these losses have been estimated to cost the U.S. swine industry approximately $46 million annually (Ritter et al., 2009a). The objectives of this paper are to: 1) define transport losses in market weight pigs; 2) estimate the incidence of transport losses; 3) discuss seasonal variation in dead and non-ambulatory pigs; 4) describe the symptoms and metabolic characteristics of fatigued pigs; 5) review pre-disposing factors for transport losses; and 6) outline management strategies to reduce these losses under commercial conditions.
TERMINOLOGY / DEFINITIONS

Dead and non-ambulatory pigs are most commonly observed during unloading at the packing plant, but these losses can occur at any stage of the marketing process from loading at the farm to stunning at the plant. Transport losses at U.S. packing plants include:

- Dead on arrival (DOA) – a pig that died during transportation
- Dead in yard (DIY) or dead in pen (DIP) – a pig that died after unloading at the plant
- Non-ambulatory pig – a pig unable to move or keep up with the rest of the group at the plant

There are two types of non-ambulatory pigs observed under U.S. commercial conditions:

Fatigued  Injured

Fatigued pigs are pigs without obvious injury, trauma, or disease that refuse to walk at any stage of the marketing process from loading at the farm to stunning at the plant. Meanwhile, injured pigs have a compromised ability to move due to structural unsoundness or due to an injury sustained during the marketing process (Ritter et al., 2009a).

INCIDENCE OF DEAD PIGS AT PACKING PLANTS

The percentage of dead pigs at USDA inspected plants is reported to the Food Safety Inspection Service (FSIS) as “swine condemned ante-mortem for deads”. These national statistics are available to the public via the Freedom of Information Act and take into account all dead pigs at the packing plant (i.e., dead on arrival, euthanized, dead in pen, and yard deads). The annual data on the percentage of dead pigs at USDA inspected packing plants for the calendar years of 1991 through 2010 are presented below in Figure 1 (FSIS, 2007; 2008; 2009; 2010; 2011).

1991 to 2001

The incidence of dead pigs at U.S. plants was very low in 1991 (0.08%) and 1992 (0.07%). However, the percentage of dead pigs at U.S. plants increased three-fold between 1993 and 1998 (Figure 1; 0.10% and 0.30%, respectively) (FSIS, 2007). It is unclear why this value increased over this period, but some potential explanations include changes in genetics, increased live weights, and increased size of production operations (Ellis et al., 2003). From 1998 to 2001, the percentage of dead pigs peaked and remained relatively constant (range: 0.28% to 0.30%; Figure 1) (FSIS, 2007).
Figure 1. Percentage of dead pigs at USDA inspected plants by year from 1991 to 2010 (FSIS, 2007; 2008; 2009; 2010; 2011).

2002 to 2010

From 2001 to 2002, the percentage of dead pigs at U.S. plants decreased from 0.29% to 0.22% (Figure 1) (FSIS, 2007). This decrease might be attributed to greater industry awareness of losses during the marketing process. In 2002, the National Pork Board’s Transport Quality Assurance™ (TQA™) program was made available, and there was a strong focus on research that yielded important results (Anderson et al., 2002; Ellis et al., 2003; NPB, 2004).

The percentage of dead pigs at the plant then leveled off at 0.22% during the years of 2002 to 2006 (Figure 1) (FSIS, 2007). It is currently unknown why little change was made over this time period. However, it is important to note that during this same time period, several packers began to euthanize non-ambulatory pigs that had a low likelihood of recovering, and these pigs were reported as dead pigs to FSIS. Therefore, the definition of a dead pig at USDA inspected plants has recently changed and now includes pigs that are euthanized at the plant (Ritter et al., 2009a). Another important fact to consider is that porcine circovirus type 2 (PCV2) had a major impact on the health and mortality of finisher pigs marketed over this time period as the first commercial vaccine was not available in the U.S. until July of 2006 (Gillespie et al., 2009; Kristensen et al., 2011).

Meanwhile, dead pigs at the packing plant have decreased over the last four calendar years to 0.17% in 2010 (FSIS, 2007; 2008; 2009; 2010; 2011). This improvement may be attributed to pork producers and packers working together to implement proactive management strategies to prevent / minimize transport losses. For example, on-farm and in-plant training programs,
standard operating procedures for pig handling and transportation, loading assessments, handling audits, and databases for transport losses have evolved significantly over the past four years.

INCIDENCE OF NON-AMBULATORY PIGS AT PACKING PLANTS

Unfortunately, national statistics are not available for the percentage of non-ambulatory pigs at the plant, and thus, commercial field trials are currently our best indicator of the incidence of non-ambulatory pigs in the U.S. A total of 23 commercial field trials have been conducted in the U.S. and the results from these studies have recently been summarized (Ritter et al., 2009a). The percentage of dead pigs, non-ambulatory pigs, and total losses (dead and non-ambulatory) at the plant averaged across the 23 field trials (n = 6,660,569 pigs) were 0.25% for deads, 0.44% for non-ambulatory pigs, and 0.69% for total losses. Non-ambulatory pigs were classified as fatigued or injured in 18 of these field trials, and the rates of fatigued and injured pigs averaged across these 18 field trials (n = 4,966,419 pigs) were 0.37% and 0.05%, respectively. Therefore, the majority of non-ambulatory pigs at the plant in U.S. field trials were classified as fatigued.

SEASONAL VARIATION IN TRANSPORT LOSSES

Figure 2 illustrates the monthly incidence of dead market pigs at USDA-inspected plants for the calendar year of 2010. The months of July, August, and September had higher rates of dead pigs than the 2010 average of 0.17% (FSIS, 2011). This comes as no surprise as it is well documented that the percentage of dead pigs at the packing plant is highest during the summer months (Rademacher & Davies, 2005; Ellis & Ritter, 2006; Ritter, 2008). Meanwhile, several U.S. field studies have reported that the rates of non-ambulatory pigs are the highest during the late fall and early winter months (Rademacher & Davies, 2005; Ellis & Ritter, 2006; Ritter, 2008). It is currently unknown why the rate of non-ambulatory pigs increases during the late fall and early winter months. However, some potential explanations include: temperature stress, heavier market weights, increased numbers of pigs being harvested, and changes in health status (Ellis & Ritter, 2006).

SYMPTOMS AND METABOLIC CHANGES IN FATIGUED PIGS

Fatigued pigs display signs of acute stress (open-mouth breathing, skin discoloration, and/or muscle tremors), are in a metabolic state of acidosis (characterized by low blood pH and high blood lactate values), and may have elevated body temperatures (Ritter et al., 2009a; Gonyou H.W., unpublished). However, controlled research has demonstrated that the vast majority of fatigued pigs will metabolically recover, if the stressors are removed, and pigs are allowed to rest for 2 to 3 hours (Anderson et al., 2002; Hamilton et al., 2004; Ritter et al., 2006).

It is interesting to note the striking similarities between the symptoms and metabolic characteristics of fatigued pigs to those of pigs with Porcine Stress Syndrome (Ritter et al., 2009a; Topel et al., 1968; Topel et al., 1981). A recent commercial field trial involving 2,109 pigs was conducted at four Midwestern U.S. packing plants to determine the impact of the HAL-1843 mutation on the incidence of dead and fatigued pigs at U.S. packing plants. This study demonstrated that 98% of the normal pigs, 95% of the dead pigs, and 98% of the fatigued pigs evaluated were negative for the HAL-1843 mutation (Ritter et al., 2008a). This suggests that the HAL-1843 mutation has basically been eliminated from the U.S. commercial pig population, and
thus, has only minor effects on the overall incidence of dead and non-ambulatory pigs at the packing plant.

Figure 2. Percentage of dead pigs at USDA inspected plants by month in 2010 (FSIS, 2011).

PRE-DISPOSING FACTORS FOR TRANSPORT LOSSES

Transport losses are a multi-factorial problem consisting of people (handling tools and handling intensity), pig (genetics, diet, gut fill, live weight, gender, health status, and previous handling experiences), facility design (pen size, pre-sorting strategies, aisle width, distance moved, and loading ramp angle), transportation (trailer design, mixing of unfamiliar pigs, loading density, and length of journey), packing plant (waiting time at the plant, unloading procedures, distance moved, facility design, and lairage time), and environmental factors (season, temperature, relative humidity, and trailer settings for bedding, boarding, and misting) (Ritter, 2008).

Of these fore-mentioned factors, it is well established that transport losses are increased by:

1. The HAL-1843 mutation (McPhee et al., 1994; Murray & Johnson, 1998; Fàbrega et al., 2002)
2. Aggressive handling with electric prods (Benjamin et al., 2001; Gonyou, unpublished)
3. Crowding pigs during transport (Ritter et al., 2006; 2007; Ritter, 2007)
4. Extreme weather conditions (heat stress and cold stress) (Ellis & Ritter, 2006; Ritter, 2008)
MANAGEMENT STRATEGIES TO REDUCE TRANSPORT LOSSES

Pre-slaughter stressors have additive effects on the stress responses (rectal temperature, blood lactate, and blood pH values) of market weight pigs (Ritter et al., 2009b). Therefore, removing just one stressor during the marketing process can improve the pig’s well-being and can potentially reduce transport losses at the plant. Management strategies to reduce transport losses under U.S. commercial conditions include preparing pigs for transport, improving facility design, minimizing stress during handling, and optimizing transport conditions. Below is a summary of recent research and key findings on these topics.

Prepare pigs for transport

1. **Previous handling.** Stewart et al. (2008) evaluated the effects of previous handling on loading time, physical signs of stress during loading and unloading, and transport losses at the packing plant. Previous handling treatments (control vs. previous handling) were implemented the day before loading. Pigs assigned to the previous handling treatment were moved out their barn pen to an outside load-out area, were turned around, and returned to their home pen by two handlers. Meanwhile, control pigs were not handled and remained in their original barn pens. These authors reported that previous handling reduced loading time, pigs exhibiting open-mouth breathing and skin discoloration during loading, and tended to reduce total transport losses (0.07% vs. 0.38%) compared to pigs that were not previously handled.

2. **Feed withdrawal.** Two U.S. commercial trials have evaluated the effects of feed withdrawal on transport losses at the packing plant. Ritter (2007) compared pigs fasted for 0 or 24 h prior to loading and reported that 24 h feed withdrawal reduced total transport losses by 50% compared to the control treatment, but these results were not statistically significant (0.18% vs. 0.36%; P = 0.31). In a follow-up trial involving 14 loads of pigs, Stewart et al. (2008) compared pigs fasted for 0 or 16 h prior to loading and reported that 16 h feed withdrawal significantly reduced total transport losses (0.0% vs. 0.39%). Collectively, these two commercial field studies suggest that feed withdrawal may reduce transport losses in market weight pigs, but additional research involving a larger number of animals are needed to confirm these findings.

Improve facility design

1. **Loading distance.** Loading distance refers to the distance pigs are moved from the barn pen to the trailer during loading. Two commercial field trials have evaluated the effects of loading distance on transport losses at the packing plant (Ritter et al., 2007; 2008b). These studies compared pigs moved short (front 1/3 of the barn) vs. long distances (back 1/3 of the barn) during loading. Both studies reported that pigs moved long distances during loading tended to have higher rates of non-ambulatory pigs at the farm than pigs moved short distances. However, after a 3 to 4 h journey to the packing plant, there was no effect of loading distance on dead or non-ambulatory pigs at the packing plant.

2. **Large pens with pre-sorting capabilities.** Raising grow-finish pigs in large pens with pre-sorting capabilities has important implications for minimizing stress during loading and reducing transport losses at the packing plant because: 1) large pens allow pigs to have more room to exercise during the grow-finish period; 2) pre-sorting allows market weight pigs the opportunity to rest and recover from the stress of being sorted from pen mates; 3) pre-sorting enables producers to withdrawal feed on all pigs marketed; 4) pre-sorting may reduce the distance pigs are moved during loading, if pre-sort pens are located by the barn exit; and 5) loading pigs from
large pens may reduce the number of unfamiliar pigs that are mixed during transportation. Barns with auto-sort systems house pigs in pens of approximately 500, require pigs to walk across a scale before entering a food court, and automatically pre-sort market weight pigs from pen mates prior to loading. Two U.S. commercial surveys have reported that pigs raised in barns with auto-sort systems have fewer dead pigs at the packing plant than pigs raised in traditional finishing barns with small pens that were not pre-sorted prior to loading (Brumsted, 2004; Rademacher & Davies, 2005). Furthermore, a few large production systems in the U.S. are raising pigs in large pens (≥ 200 pigs/pen) with internal swinging gates that are used to manually pre-sort market weight pigs from pen mates prior to loading. This new facility design system was recently evaluated by Johnson et al. (2010), who compared pigs raised in small pens of 32, not pre-sorted prior to loading vs. pigs raised in pens of 192, pre-sorted 24 h prior to loading. This study demonstrated that raising pigs in large pens and pre-sorting prior to loading reduced dead and non-ambulatory pigs at the packing plant by 66% compared to the traditional grow-finish design (pens of 32, not pre-sorted). However, additional research is necessary to determine if this improvement is due to raising pigs in large pens and/or the management practice of pre-sorting market weight pigs prior to loading.

3. Loading ramp design. Berry (2007) compared the handling characteristics and transport losses of market weight pigs loaded at the farm by using a traditional metal covered chute or a prototype loading gantry. The prototype loading gantry was used to load both the bottom (7° ramp angle) and top (18° ramp angle) decks of the trailer. Meanwhile, the traditional chute was used to load only the bottom deck of the trailer (19° ramp angle), while the internal trailer ramp was utilized to load the top deck (23° ramp angle). The number of shocks administered from an electric prod, slips, falls, vocalizations, and pile ups observed during loading were reduced by using the prototype loading gantry compared to the traditional chute. Furthermore, the percentage of total transport losses at the packing plant was lower for pigs marketed on the first cut with the prototype loading gantry compared to the traditional chute, but there were no treatment differences between loading chutes for transport losses on the close-out loads. Additional research is necessary to evaluate the different components of loading chute design (ramp angle, chute width, flooring, lighting, covered vs. uncovered, etc.) and their impact on dead and non-ambulatory pigs at the packing plant.

Minimize stress during handling

1. Flight zone and point of balance. The flight zone refers to the animal’s personal space or comfort zone (NPB, 2004; Grandin, 2008). When a handler enters the flight zone, the animal will move away in the opposite direction from the handler. Meanwhile, the point of balance is located directly behind the shoulder. Where the handler stands or taps the pig in relation to the point of balance will dictate which direction the pig will move. McGlone et al. (2004) conducted a study to determine the optimal place to tap or shock pigs in order to move them forward. This study compared tapping or shocking pigs with plastic paddles or electric prods on the ham, neck, rear leg, back, left side or right side. These authors confirmed that the most effective area to tap or shock a pig to move it forward is on the back behind the point of balance.

2. Handling tools. Three common handling tools that are used at the farm during loading include: sorting boards, plastic livestock paddles, and if necessary, electric prods. In a recent study (McGlone et al., 2004), pigs were moved through a handling course with one of three different handling tools (sorting board vs. electric prod vs. plastic paddle) and the time to
complete the course for each group of pigs was recorded. Pigs moved with sorting boards required less time to complete the handling course than pigs moved with only plastic paddles or electric prods. The authors concluded that the sorting board is the single most effective tool for moving pigs. Therefore, all handlers and drivers need to use a sorting board when loading pigs.

3. **Handling intensity.** Handling intensity refers to the pace in which pigs are encouraged to move during handling. It is well documented that aggressive handling with electric prods increases rectal temperature, blood lactate values, and the percentage of fatigued pigs during handling (Benjamin et al., 2001; Anderson et al., 2002). Furthermore, a recent study by Gonyou (unpublished data) compared moving market weight pigs through a handling course with three different handling treatments: 1) gentle handling with plastic paddles; 2) aggressive handling with plastic paddles; and 3) aggressive handling with electric prods. When pigs were handled aggressively with electric prods, 34% of the pigs were classified as fatigued immediately after the handling procedure. If the electric prod was replaced with a plastic paddle and the pigs were still moved aggressively, a 19 percentage point reduction in fatigued pigs was observed. However, there was an additional 13 percentage point reduction in fatigued pigs, if pigs were moved a slow and calm pace with a plastic paddle. These data demonstrate the negative effects of aggressively handling pigs with electric prods on transport losses and highlight the importance of moving pigs at a slow and calm pace with a plastic paddle.

4. **Electric prod use.** As mentioned above, it is well documented that aggressive handling with electric prods increases the rate of fatigued pigs (Benjamin et al., 2001; Gonyou, unpublished data). Therefore, electric prods should only be used as a last resort to move pigs. Unfortunately, the acceptable number of shocks that can be applied to market weight pigs during handling is currently unknown as there is a limited amount of published data on the effects of minimal electric prod use on stress responses during handling. Ritter et al. (2008c) compared the stress responses of 48 market weight pigs moved through a handling course with 0, 2, or 4 shocks from an electric prod. The pigs evaluated in this study were allowed to move at their own pace, the duration of the shocks was ≤1 second, and pigs assigned to the 0 shocks treatment were moved with a plastic paddle. These authors reported that pigs moved with 4 shocks had higher rectal temperatures and blood lactate values than pigs moved with 0 shocks, but pigs moved with 2 shocks had similar rectal temperatures and blood lactate concentrations as pigs moved with plastic paddles (0 shocks). This small study suggests that stress responses during handling can be minimized if market weight pigs are moved with ≤2 shocks/pig. However, additional research involving a larger number of pigs under commercial conditions is necessary to confirm these results and to define acceptable use of electric prods.

5. **Group size.** Berry et al. (2009) conducted a controlled commercial study to evaluate the effects of loading market weight pigs (119.9 kg) in two different group sizes (groups of 4 vs. 8) through a 76 cm wide aisle to determine the effects of group size on loading time, physical signs of stress (during loading and unloading), and transport losses at the plant. The key findings from this study were that pigs moved in groups of 4 required less time to load, had lower rates open-mouth breathing and skin discoloration during loading and unloading, and had 56% fewer dead and non-ambulatory pigs at the packing plant. These data confirm that group size during loading has a major impact on transport losses at the plant, but additional research is necessary to determine the optimal group size for moving pigs of all ages through various aisle widths.
Optimize transport conditions

1. **Trailer design.** Ritter et al. (2008b) utilized 109 trailer loads of pigs to investigate the effects of trailer design (pot-belly vs. straight-deck trailers) on handling characteristics, stress responses (during loading and unloading), transport losses, and carcass trim loss. Although pigs unloaded from pot-belly trailers took 16 min longer to unload, required more electric prod usage to exit the trailer, and exhibited a higher percentage of open-mouth breathing and skin discoloration at the plant compared to pigs unloaded from straight-deck trailers, there was no effect of trailer design on the percentage of dead pigs, non-ambulatory pigs, total transport losses, or carcass trim loss.

2. **Transport floor space.** Transport floor space refers to the amount of space that pigs are provided on the trailer during transportation. A series of three controlled studies were conducted under U.S. commercial conditions to determine the effects of transport floor space on dead and non-ambulatory pigs at the packing plant. These studies utilized market weight pigs (129 kg) with journey times of 2-3 h and demonstrated that transport floor space has a major impact on dead and non-ambulatory pigs at the packing plant (Ritter et al., 2006; Ritter et al., 2007; Ritter, 2007). In general, transport losses were minimized in these studies when market weight pigs (129 kg) were provided with transport floor spaces of $\geq 0.46 \text{ m}^2/\text{pig}$, and this translates to loading densities of 281 kg/m$^2$ or 0.355 m$^2$/100 kg. However, it is worth mentioning that in one of the studies (Ritter, 2007), the effects of transport floor space on losses at the plant were dependent upon season, where transport floor space had a pronounced effect on transport losses in the summer months, but no effect in the winter months. Therefore, additional research is necessary to determine the optimal transport floor spaces for market hogs transported on short and long hauls over all four seasons.

3. **Mixing unfamiliar pigs during transport.** Ritter (2007) utilized 37 trailer loads of market weight pigs to determine the effects of mixing unfamiliar pigs during transport on transport losses at the plant. This study compared two treatments: mixed vs. unmixed. Unmixed groups had ~50 % numerically lower total transport losses than mixed groups, but these differences were not statistically significant (0.19 % vs. 0.37 %; $P = 0.34$). It is important to note the low percentage of dead and non-ambulatory pigs observed in this study. Therefore, additional research is necessary to evaluate the effects of mixing unfamiliar pigs during transport on farms experiencing higher rates of transport losses than those encountered in the work of Ritter (2007).

4. **Managing trailer settings for cold and hot weather.** Current U.S. recommendations for boarding / bedding trailers in cold weather and showering pigs in hot weather can be found in the National Pork Board’s Trucker Quality Assurance Handbook (2010). However, these recommendations are based on best industry practices and not on scientific studies, and this represents a large gap in the literature. Therefore, a series of controlled studies are currently being conducted in the U.S. to scientifically define boarding / bedding and showering requirements for market hogs transported in cold and hot weather, respectively.

**CONCLUSIONS**

Approximately 0.7% of all U.S. market weight pigs become non-ambulatory or die at or en route to the packing plant. In other words, over 99% of the market hogs transported in the U.S., walk off the trailer, walk through the plant, and are processed without delay. Despite the large percentage of pigs that are unaffected, these transport losses have been estimated to cost the U.S. swine industry approximately $46 million annually. Transport losses are a multi-factorial...
problem that can be influenced by growers, loading crews, transporters, and handlers at the packing plant. Management strategies to reduce transport losses under U.S. commercial conditions include better preparing pigs for transport, improving facility designs, minimizing stress during handling, and optimizing transport conditions.

LITERATURE CITED


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