Loading system effect on performance, handling and meat quality attributes of finisher pigs

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Loading system effect on performance, handling and meat quality attributes of finisher pigs

by

Nicholas Lee Berry

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Animal Science

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Ames, Iowa

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# TABLE OF CONTENTS

**ACKNOWLEDGMENTS**

**ABSTRACT**

**CHAPTER 1. GENERAL INTRODUCTION**

**CHAPTER 2. LITERATURE REVIEW**

- **GROWING PUBLIC CONCERN**
- **DEFINING LOSSES DURING HANDLING AND TRANSPORT**
- **INCIDENCE OF LOSSES**
- **COST TO THE INDUSTRY**
- **THE PIG: ITS BEHAVIOR AND ANATOMICAL FEATURES**
- **ADDITIVE STRESSORS**
- **THE PIG AND CARETAKER INTERACTION**
- **ON-FARM ASSESSMENT OF HANDLING**
- **FACILITY DESIGN**
- **LOADING SYSTEM**
- **PRESLAUGHTER STRESS**
- **HARVEST PROCESS**
- **PORK QUALITY**

**CHAPTER 3. LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON TRANSPORTATION AND PACKING PLANT LOSSES**

- **ABSTRACT**
- **INTRODUCTION**
- **MATERIALS AND METHODS**
- **RESULTS AND DISCUSSION**
- **IMPLICATIONS**
- **LITERATURE CITED**

**CHAPTER 4. LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON HANDLING AND WELFARE PARAMETERS AT THE TIME OF MARKETING**

- **ABSTRACT**
- **INTRODUCTION**
- **MATERIALS AND METHODS**
- **RESULTS AND DISCUSSION**
- **IMPLICATIONS**
CHAPTER 5. LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON MEAT QUALITY ATTRIBUTES

ABSTRACT

INTRODUCTION

MATERIALS AND METHODS

RESULTS AND DISCUSSION

IMPLICATIONS

LITERATURE CITED
ACKNOWLEDGMENTS

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ABSTRACT

Handling and transport losses can encompass several challenges experienced frequently by producers and packers alike. Marketing and transportation stress not only costs the industry due to mortalities, but has direct impact on the quality of pork delivered to the consumer (Barton-Gade, 1992; Geverink et al., 1996; Hambrecht, 2005).

The primary objective of the current study was to determine if loading system affects the incidence of losses during transportation or at the packing plant, welfare parameters at the time of marketing, and meat quality attributes. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared on the first pigs marketed from a finishing facility (first pull [FP] pigs) and on the last pigs marketed from a finishing facility (closeout [CO] pigs).

Loading system influenced the total number of dead pigs ($P < 0.06$) and total losses ($P < 0.03$) in FP pigs. Results indicated that pigs loaded on the P chute during the FP have fewer total deads and total losses. Loading system also influenced welfare parameters ($P < 0.01$) of both FP and CO pigs at the time of marketing. Pigs loaded on the P chute experienced significantly fewer electric prods, slips, falls, vocalizations, and pile ups, regardless of time of marketing.

Loading system did influence several meat quality attributes evaluated. In a comparison of FP pigs, loins from pigs loaded with the P loading system had higher ($P < 0.05$) initial and 24 h pH and tended to have higher ($P = 0.08$) JCS cut values, but lower ($P = 0.03$) loin $L^*$ values. The higher JSC cut values and lower $L^*$ values indicate a darker, redder color meat. Among CO pigs, loins from pigs loaded with the P loading system had higher ($P = 0.01$) 24 h pH and JCS rib values, but lower ($P = 0.06$) $L^*$ values.
Understanding key factors influencing losses during this time frame enables targeted interventions to improve both welfare and meat quality. This investigation has provided data to support changes in facility design that may ultimately lead to the improvement of performance, welfare, and pork quality.
CHAPTER 1.  
GENERAL INTRODUCTION

Handling and transport losses can encompass several challenges experienced frequently by producers and packers alike. The term transport loss is used loosely, but most commonly references those pigs that die during transport (dead on arrival; DOA) and pigs that become non-ambulatory during the marketing process. Most recently, fatigued pigs were defined by scientists and industry representatives as “a non-ambulatory, non-injured pig that without obvious injury, trauma, or disease, refuses to walk at any stage of the marketing channel from loading at the farm to stunning at the plant” (Ritter et al., 2005). Anderson et al. (2002) defined a non-ambulatory pig as “a pig that cannot keep up with its contemporaries during loading, unloading, or moving through the packing plant.”

Based on several field studies, the incidence of transport losses in market-weight pigs is approximately 1% (Ellis et al., 2003; Ellis and Ritter, 2006). The national average for the percentage of dead pigs at U.S. packing plants was low (~0.09%) from 1990-1993, but increased to 0.30% in 1998. In contrast to the increased prevalence of the problem experienced in the late 1990’s, it has been reported that the incidence of dead pigs at the plant has declined to 0.22% in 2004 (Ellis and Ritter, 2006). Additionally, the incidence of non-ambulatory (fatigued) pigs has been recently estimated in the range of 0.4% to 0.8% based on two large field studies conducted within two different production systems (Ellis et al., 2003; Rademacher and Davies, 2005).

As the issue pertains to pork quality, problems with color have been estimated to cost $0.43 per head, for bruising, $0.08 per head and for pale, soft and exudative (PSE)
meat, $0.90 per head (Stetzer and McKeith, 2003). This results in a total lost opportunity for the U.S. swine industry of $254,104,500 or $2.44 per finisher head per year. Grandin (1999) reported approximately 10% more pork would be suitable for high quality exports to Japan when pigs are handled quietly and usage of electric prods is reduced. Economic losses associated with pigs that die or become fatigued during transportation and at the packing plant, as well as the negative attributes associated with poor meat quality, have been estimated to cost the U.S. swine industry $300-350 million dollars annually (Ellis et al., 2003; Stetzer and McKeith, 2003).

Economic losses associated with dead and fatigued pigs are not confined to mortalities and poor meat quality. We were unable to find any research to quantify the economic impact of poor handling and transportation on the farm and packing plant employee. However, over one-third of employee injuries within finishing operations are animal handling related, of which a majority are due to sorting and loadout procedures (Hill et al., 2007a). Fatigued and dead pigs disrupt standard animal flow, resulting in reduced transportation and packing plant efficiencies. In many cases these animals require specialized handling practices to ensure their well-being and such practices result in additional use of personnel, time, and labor, thereby reducing unloading efficiency at the processing facility (Hill et al., 2007a). This investigation will provide insight to changes in facility design that may ultimately lead to the minimization of some stressors that pigs are exposed to at the time of marketing.
CHAPTER 2.

LITERATURE REVIEW

GROWING PUBLIC CONCERN

Consumers, public and private agencies, livestock producers, and research scientists have shown an increasing interest in assuring proper animal care and handling (Von Borell et al., 2005). In 2004, a group of swine well-being experts that included researchers reviewed the scientific literature pertaining to the fatigued and finisher pig transportation. Researchers and allied industry representatives concluded that transport losses may be influenced by numerous factors including genetics, carcass muscling, health status, structural soundness, body weight, nutrition, handling, facility design, and conditions during transport to the plant (Ritter et al., 2005). Researchers also challenged the industry to “improve finisher pig well-being at the time of marketing” through scientific research on facility design (Ritter et al., 2005).

DEFINING LOSSES DURING HANDLING AND TRANSPORT

Handling and transport losses can encompass several challenges experienced frequently by producers and packers alike. The term transport loss is used loosely, but most commonly references those pigs that die during transport (dead on arrival; DOA) and pigs that become non-ambulatory during the marketing process. Most recently, fatigued pigs were defined by scientists and industry representatives as “a non-ambulatory, non-injured pig that without obvious injury, trauma, or disease, refuses to walk at any stage of the marketing channel from loading at the farm to stunning at the plant” (Ritter et al., 2005). Anderson et al. (2002) defined a non-ambulatory pig as “a pig
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Marketing and transportation stress not only costs the industry due to mortalities, but has direct impact on the quality of pork delivered to the consumer (Barton-Gade, 1992; Geverink et al., 1996; Hambrecht, 2005). Economic losses associated with pigs that die or become fatigued during transportation and at the packing plant, as well as the negative attributes associated with poor meat quality, have been estimated to cost the U.S. swine industry $300-350 million dollars annually (Ellis et al., 2003; Stetzer and McKeith, 2003).

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The majority of processors are now not only charging the cost of a dead on arrival (DOA) pig back to the producer, but are also charging the cost of an animal received in a compromised state, regardless of whether processed for consumption or rendered as a byproduct. In addition, many processors are charging a fee to offset the extra labor cost, loss in efficiencies, and liability associated with handling compromised pigs (Hill et al., 2007a).

To ensure the humane handling of these animals and to adhere to the Humane Slaughter Act, many processing facilities have devoted highly trained personnel to their
lairage department, which has significantly increased lairage labor costs. Adding to this, the specialized equipment necessary to properly handle fatigued pigs requires significant investment in not only capital expenditures by the processing facility, but also increases the maintenance requirements (Hill et al., 2007a).

**THE PIG: ITS BEHAVIOR AND ANATOMICAL FEATURES**

In order to provide an efficient system to handle market pigs and load them properly, it is of utmost importance to have a thorough understanding of their composition and physical attributes. In recent years pigs have been bred for increased muscle development, with today’s finisher pig weighing between 250-300 pounds. Typically, pigs at this weight have a shoulder width of approximately 14 inches and a total length exceeding 54 inches from snout to tail tip (Nabil, 1998).

Pig behavior is dictated by cues received from the environment, utilizing basic sensory capabilities to study surroundings. The pig has a wide peripheral vision of approximately 310 degrees, but only a 12 degree field of best vision (Heffner and Heffner, 1992). Similar to other animals, pigs have a blind spot directly behind them and are only moderate judges of distance. Therefore people, changes in illumination intensities, moving objects, and contrast in color will result in hesitation and balking during handling (Grandin, 1989).

The auditory system of the pig has a range of frequency detection between 40 Hz and 40k Hz, which is slightly elevated compared to humans (Heffner and Heffner, 1990). Loud, high pitched noises seem to be aversive to pigs (Talling et al., 1996), including high pitched vocalizations emitted by pigs experiencing traumatic events. Pigs have an acute sense of smell, and logically use a wide range of olfactory cues when studying their
surroundings (Curtis et al., 2001). The snout is the primary organ of touch for the pig. However, pigs can also detect changes in surfaces through nerve endings in the skin and various subcutaneous tissues. The pig is also efficient at using the foot pad to identify changes in flooring texture and will hesitate at surfaces that are new or aversive.

Pigs are social creatures that desire to remain in groups. In most instances pigs prefer to maintain visual, if not physical contact with their pen mates (Hill et al., 2007a). When pigs are isolated from groups they become highly agitated. Commonly, the resulting excitement of the individual animal negatively impacts the behavior of the entire group, which can certainly be detrimental during times of pig movement or loadout.

**ADDITIVE STRESSORS**

Throughout all phases of production, the pig is subjected to a constant barrage of stressors. Stressors that impinge on pigs vary in time (frequency and duration), intensity (density and area), mode (visual, emotional, etc.) and degree of novelty (Coleman et al., 2002). It has been suggested that transport losses are a multi-factorial phenomenon (Anderson et al., 2002; Ellis et al., 2003). Dead and non-ambulatory pigs may be influenced by various aspects of the pig (genetics, live weight, muscling, gender, diet, gut-fill, health status, and previous handling experiences), facility design (aisle width, flooring, ventilation, distance moved during loading, and loading systems), people (attitude, stockmanship, handling intensity, and handling device), transport (trailer design, mixing during transport, transport floor space, transport time/distance, transport conditions, and driver), plant (wait time prior to unloading, unloading procedures, lairage
time, stunning equipment, and line speed), and environmental (season, temperature, and relative humidity) factors (Ritter et al., 2005).

Despite these challenges, the pig has developed physiological mechanisms to adapt to both acute and chronic stressors that are neutral, negative, or positive in regards to their effects on well-being. It is only when the stress level exceeds the body’s capacity to cope in a reasonable time frame that the pig’s well-being is compromised. The inability to cope will result in loss of efficiency and long term harm with the ultimate extreme being death (Hemsworth et al., 1994). Novelty (handling, loading, and mixing) can be a profound stressor to pigs (English, 1991; Knowles and Warriss, 2000; Moberg and Mench, 2000), and is especially evident when the novel experience is aversive. How an individual pig copes with such aversive stimuli can affect its overall performance and meat quality (Grandin, 1989; Grandin, 1993; Grandin, 1997; Coleman et al., 1998).

The process of transportation can be visualized as “additive stressors” as proposed by McFarlane and Curtis (1989); McFarlane et al. (1989a); and Broom and Johnson, (1993). Over a given period of time, the pig is exposed to one stressor after another and the animal does not have time for its body to return to baseline. Each time a new stressor is added, the stress response of the animal continues to become more intense. At some point, if the animal does not have time to recover, then the ultimate end-point can be death (Figure 1.1 and 1.2).

THE PIG AND CARETAKER INTERACTION

In commercial production systems, caretakers can be your greatest asset or your greatest liability (Hill et al., 2007). Good animal handlers that understand animal behavior, production systems, and their impact on pork quality can minimize the impact
of poor design (Hill et al., 2007a). However, the best facility design can be rendered
inadequate by poor animal handling. The basics of animal handling have been well
defined and highly publicized in the swine industry, but it is becoming apparent that
continual training and performance monitoring are necessary to maintain a high level of
success.

An animal handler’s primary objective is to minimize the pigs’ level of fear and
negate moments of negative stress. This can be achieved by maximizing positive
interactions while encouraging the animal to move to the target location. Movement of
pigs is achieved by understanding their point of balance as well as careful manipulation
of the edge of their flight zone (Figure 1.3). For example, if the caretaker wishes to move
a pig forward they need to stand behind the point of balance. Conversely, if the caretaker
desires to back a pig up, standing in front of the point of balance will aid in this line of
movement. Pigs can often times be moved by understanding and utilizing the point of
balance without ever employing a moving aid.

Ease of routine movement and handling of pigs can be enhanced by an array of
handling tools available to the producer (McGlone et al., 2004; Ritter et al., 2005). The
most common handling aids recommended by the swine industry to move finisher pigs
include sort boards, large flags, or plastic paddle sticks (NPB, 2002).

Recent work by McGlone et al. (2004) compared an electric prod (1700 mA),
with a paddle that had a plastic handle, a plastic sorting board with no handle, and a black
flag on their effectiveness to move finisher pigs. The data clearly demonstrated that
while both the prod (~120 sec) and paddle (~125 sec) were effective in moving pigs, the
plastic sorting board was the most effective (~80 sec). Finally, the authors compared the
plastic sorting board with a flag and reported that there was no difference for pigs moved with either the flag (~60 sec) or plastic sorting board (~38 sec). The pigs seemed to view the board and flag as a solid impassable wall, unless they could see around the edges. If pigs observed an opening around the edges they attempted to exploit this by trying to pass through the hole.

In comparison, it has been clearly demonstrated that the use of electric prods will increase the time required for movement, resulting in approximately 15% of the pigs to “jump” when the electric prod was applied, significantly increase vocalizations, and cause a higher level of fatigued pigs received at the plant (McGlone et al., 2004). If regular use of an electric prod is needed, the adequacy of the handling facilities should be examined (Grandin and Deesing, 1998; Grandin, 2006). If a pig is prodded several times in rapid succession with an electric prod, its heart rate, body temperature, incidence of open mouth breathing, and blood lactate levels will increase significantly, indicating that the pig is experiencing a stressor(s), which in turn can affect not only well-being, but their meat quality (Grandin, 1993). Additionally, some work on previous experiences that pigs have with being handled (a term known as “walking the pens”) for brief periods before loadout can reduce the novelty, and therefore the stress associated with the loadout experience (Grandin, 1997; Geverink et al., 1996).

The role of the caretaker in maintaining the well-being and productivity of farm animals has received increasing attention over recent years (Seabrook, 1972; Hemsworth et al., 1989; English, 1991; Hemsworth et al., 1993; Hemsworth et al., 1994). Some of the emphasis in previous research has been placed on caretaker personality variables such as introversion, retroversion, and neuroticism (Seabrook, 1972). However, the strongest
predictors of caretaker behavior have been found to be related to their attitudes (Broom and Johnson, 1993; Hemsworth et al., 1994; Coleman et al., 1998). Caretaker behavior has been shown to be strongly related to fear and reproductive performance in pigs (Hemsworth et al., 1989). It has also been proposed that empathy of the caretaker may be related to the well-being and productivity of animals under their care (English, 1991; Hemsworth et al., 1994). A group based in Australia has done extensive work on the role of the caretaker in relation to pig fear and subsequent effects on performance. In one study, Hemsworth et al. (1994) studied 25 commercial farms and compared a no training (control group) to a “attitudinal–behavioral modification” treatment which consisted of a cognitive–behavioral intervention procedure designed to modify the behavior of caretakers toward pigs. The effectiveness of the intervention program was assessed by monitoring the changes in the attitudinal and behavioral profiles of caretakers and the behavior and reproductive performance of pigs. Results indicated that after training there were significant improvements in the attitude and behavior of the caretaker towards pigs, the behavioral response of pigs to humans, and a trend towards improvement in pig reproductive performance. No such improvements were observed in the control treatment.

**ON-FARM ASSESSMENT OF HANDLING**

Animal movement is accomplished by making the target location, or route to it, more attractive than the starting location (Gonyou, 1993). Pigs are motivated by many factors including natural curiosity, odors, sounds, food, and fear (McGlone et al., 2004). Traditional handling and loading systems have been either poorly planned or not planned in the design and construction of a finishing facility. Therefore, during handling and
marketing opportunities, the industry is forced to rely heavily on negative motivators or repulsive forces, most notably fear and pain, to move the animal (Hill et al., 2007b).

The goal of any handling and loading system should be to provide a continuous unidirectional flow of pigs from the pen to the trailer, with minimal amount of stress on the animal. However, due to the inherent variation in production facilities, management styles, transportation systems, and processor requirements, there will never be a single ideal handling procedure (Hill et al., 2007b).

To maintain a high level of success requires constant vigilance and evaluation of the production system to identify areas for improvement (Hill et al., 2007b). This requires collaborative efforts between the producer, transport company, and processor. At minimum, the factors that should be continuously monitored (TQA, 2002) are average live weight of pigs, load time (on a per pig basis), death loss (in transit and at the plant), non-ambulatory pigs, and an explanation for incurred loss (lame, fatigued, etc.). Additional information including loading personnel, driver, trailer identification, electric prod usage, slips/falls percentage, and chute integrity can be useful for improvement of the loading system (Grandin, 1997).

**FACILITY DESIGN**

Over 95% of the market pigs in the U.S. are raised in confinement facilities with barren environments and limited interaction opportunities for environmental enrichment or human interaction (Hill et al., 2007b). Pigs load best in a highly controlled, consistent environment that eliminates distractions and mimics the features of the home pen. This control should include all minor aspects of the pigs’ environment, such as wall coloration, lighting, flooring material, airflow patterns, etc. (Hill et al., 2007b).
Controlling all factors in the pigs’ physical environment minimizes the impact of the one (or more) factor(s) that at the time of handling and loadout is undesirable. Examples of disruptive environmental challenges include unusual wind patterns in a naturally ventilated barn, unusual light patterns, or rain on the top of the trailer creating high levels of noise.

Alleyways and loading chutes should not only be designed based on the desired size of the movement group, but also the space required to accommodate the shoulder width of the pig (Hill et al., 2007b). The goal of any design should aid in the minimization of jamming or piling events during pig movement. Current recommendations for 24-inch alleyways are based on movement of groups of three finisher pigs, and a 36-inch alleyway has been identified for group sizes of six pigs (Warris et al., 1992). However, in contrast to earlier recommendations (Grandin, 1993), some finishing units are adopting technologies from processing facilities and are incorporating wider alleyways (~ 6 ft). Spacious alleyways when paired with wider finishing facility exit doors and wider loading doors on trailers have been very successful for movement of larger groups (15 or more) of pigs (Grandin, 1993). The move to wider alleyways is supported by research indicating pigs moved 36% faster in a wider alley that allowed for group movement patterns compared to single file alleyways (McGlone et al., 2004).

Additionally, facility design should take into account the elimination of corners during loadout procedures (Hill et al., 2007b). Warris et al. (1992) demonstrated that “the presence of a bend with an angle of 45 degrees slowed the pig movement by 10%, a bend of 90 degrees slowed movement by 19%, and a bend of 180 degrees slowed movement by 44%.”
LOADING SYSTEM

Similar to facility design, the loading system needs to be appropriately configured to support movement of pigs. It has been recognized that handling and loading is one of the most stressful events for the pig (McFarlane et al., 1989a; Trunkfield and Broom, 1990; Geverink et al., 1998) because of the physical exertion required, noise exposure, and the effects of contact with people during handling.

Phillips et al. (1987) demonstrated that pigs reared in confinement would move up a ramp illuminated at 80 lux, which was similar to their living quarters, but avoided dimly lit or brightly lit facilities. In order to capitalize on this concept, some facilities slowly increase illumination along alleyways as this encourages animal movement. However, the lighting system should provide a soft, even, diffuse illumination pattern that minimizes glaring of light and shadows (Hill et al., 2007b).

It is impossible to properly handle pigs on slippery surfaces with poor footing (Grandin, 1997). Applegate et al. (1988) demonstrated significantly increased slippage with flooring materials that had a British Pendulum Number (BPN) less than 60. Currently, slippage of pigs during movement through the loading chute is combated with use of a very aggressive cleat design. Unfortunately, this design still allows for loss of footing between the cleats and under certain circumstances can result in injury to the pig’s foot pad and dew claws (Hill et al., 2007b). Pigs often times hesitate when forced to experience novel flooring materials or abrupt changes in the flooring surface. It has been recently recommended that improvement in handling efficiency may be achieved if the flooring material implemented in the loading system mimics the texture and color of the home pen flooring (Hill et al., 2007b).
Mayes and Jesse (1980) reported that throughout the entire marketing process the highest heart rate was observed when pigs climbed loading chutes. Based on current recommendations, the majority of loadout chutes range in angle from 20 to 25 degrees. Depending on the trailer design, the chute may be raised to the upper deck of the trailer or utilize the internal trailer ramp (normally 25 degrees). Research has demonstrated that each degree increase in ramp angle results in a 4% increase in heart rate and an increase in time to load of 4% for any angle greater than 20 degrees (Figure 1.4). Mayes and Jesse (1980) reported that if the individual pig’s heart rate exceeded 220 to 240 beats per min pigs would stop moving or lie down. Gonyou (1993) hypothesized that for pigs the difficulty in climbing loading chutes is mainly psychological.

Brown et al. (2005) subjected groups of pigs to three different loading systems and analyzed the differences between subjective handling scores, time to load, skin temperature, heart rate, and salivary cortisol. The systems included in the experiment were a “hydraulic tail-lift,” a “tail board ramp” at an angle of 18 degrees, and an enclosed “modular system.” Loading was subjectively assessed as being easiest and quickest using the “modular system,” which also appeared to be less physically challenging for the pigs, as evidenced by lower heart rate and reduced maximum heart rate. However, pigs loaded with the “modular system” had elevated cortisol levels during the loading and resting periods. Researchers interpreted the elevation in cortisol to some small degree of stress associated with the “modular system”, where pigs were unable to “settle in.”

PRESLAUGHTER STRESS

Rosenvold and Andersen (2003) recently exposed pigs to a no stress or stress imposed (exercise on a treadmill) treatment prior to harvest and determined that the
degree of pre-slaughter stress had a marked effect on muscle temperature early postmortem and pH decline in some pigs which was crucial to color development and color stability. Similarly, Kuchenmeister et al. (2005) concluded that applied stress (5 min before harvest) from an electric prod resulted in an increased heart rate, lower early (0 and 45 min) postmortem pH, higher Minolta L* values, and approximately 2% more drip loss when compared to a nose snare and control (no imposed stress) treatment.

Van der Wal et al. (1999) measured the effect of a short period of standardized moderate preslaughter stress just before stunning on meat quality. Stress was applied when pigs were moved from lairage to the stunning area and initial and ultimate pork quality was evaluated. Pigs were moved to the stunning area in pairs where one animal was stunned immediately, and the other was gently forced through the stunning pen, occasionally using an electric prod for 1 minute. Subjective assessment of meat quality attributes showed a tendency to reduced water holding capacity and paler color in stressed animals. At 45 minutes postmortem, rigor appeared to be accelerated and initial pH was lower in the stressed animals. Van der Wal et al. (1997) suggested that handling practices can account for 10-15% of the variation in PSE.

D’Souza et al. (1998) determined the effect of preslaughter handling on several pork quality traits by comparing pigs that had received electric prods (15 prods during a 5 minute time period before harvest) and pigs that received zero prods. It was reported that negative handling (electric prod use) of pigs just prior to harvest resulted in pork that had a higher surface exudate and a higher incidence of PSE compared with pigs minimally (no electric prods) handled prior to harvest. Subsequently, the use of electric prods to
move pigs on-farm and at the abattoir prior to harvest has the potential to negatively affect pork quality and increase the incidence of PSE pork (Grandin, 1991).

**HARVEST PROCESS**

Differences among harvest techniques and chilling practices in today’s commercial pig abattoirs can have a large impact on the development of pork quality. Relatively low pH combined with high muscle temperature during the early postmortem period causes denaturation and reduced solubility of sarcoplasmic proteins (Sayre and Briskey, 1963; Scopes, 1964; Joo et al., 1999) and myosin (Offer, 1991; Warner et al., 1997). This phenomenon leads to the prevalence of PSE carcasses seen in many of our packing plants and is a challenge not only for the fresh pork retail sector, but also for meat cuts targeted for further processing.

Currently, the two most common methods used to render the animal unconscious are electric and carbon dioxide stunning (Velarde et al., 2000). The effect of stunning method on the incidence of PSE pork was recently evaluated at four commercial pig abattoirs; two equipped with electrical stunning systems were compared with two abattoirs equipped with carbon dioxide stunning systems (Velarde et al., 2000). Abattoirs equipped with electrical stunning systems were found to have an increased incidence of PSE meat.

Gardner et al. (2006) reported that lengthening the duration of dwell and scalding time may result in a more rapid postmortem pH decline. Similarly, carcasses scalded for 8 minutes as compared with a 5 minute treatment group, had greater semimembranosus temperatures at 2 hours postmortem and loin chops with lower hue angle and greater Warner-Bratzler shear values. Springer et al. (2003) recently evaluated the differences
between accelerated chill and conventional chill systems. Their findings revealed that loin muscle pH was higher for carcasses that were chilled in the accelerated (blast) system for longer than 60 min. Accelerated chilling caused loins to be darker (lower L* values) and increased water holding capacity in fresh hams. Hambrecht et al. (2004) studied the differences between chilling (accelerated vs. conventional) and pigs exposed to preslaughter stress (pigs handled normally vs. pigs stunned with an electric prod). Researchers reported that preslaughter stress affected temperature and pH measured in both the blood and muscle, with higher temperatures and lower pH values for pigs exposed to high stress. Interestingly, the authors also found that accelerated chilling could not compensate for the negative effect of preslaughter stress on drip loss, filter paper moisture absorption, and meat color (L* value). Based on the findings reported it appears that the pork industry needs to focus on a “whole systems” approach to combating issues associated with the production of inferior pork.

**PORK QUALITY**

Meat quality has been defined by Van der Wal et al. (1997) as a blend of different properties influenced by biochemical processes that can affect consumer acceptance and/or technological aspects. Red, firm, and non-exudative (RFN) pork is considered to be the ideal pork product desired by consumers based on both color and textural attributes. The National Pork Producers Council (NPPC) Pork Quality Solutions Team established pork quality targets in order to define the ideal quality benchmark (NPPC, 1998). Acceptable lightness (L*) is measured objectively using a Minolta colorimeter and ranges from 37 to 49. Ultimate pH should be between 5.6 and 5.9. Additionally, ideal pork should have less than 2.5% drip loss when measured at 24 hours postmortem.
Red, firm, and non-exudative pork exhibits the aforementioned attributes desired by the quality benchmarking system.

Pale, soft, and exudative (PSE) pork is characterized by its pale color and inferior water-holding capacity. The product is very watery in appearance and flaccid in texture. The National Pork Benchmarking Audit found that live weight and carcass muscle percentage have increased, and backfat thickness has decreased over the last ten years (Stetzer and McKeith, 2003). As selection for leaner pigs with maximized muscularity has occurred, so has the increased occurrence of PSE pork (Lonergan et al., 2001). A survey consisting of fourteen packing plants revealed that approximately 16% of pork produced exhibited PSE characteristics (Kauffman et al., 1992). The Pork Quality Chain Audit (Cannon et al., 1996) and the National Pork Producers Council (NPPC, 1991) also found that greater than 10% of all pork carcasses generated in the U.S. contained PSE meat.

Pale, soft, and exudative pork characteristics are hard to induce in pigs that are less susceptible to stress, suggesting that there is a complex physiological and genetic difference among genetic lines that causes some pigs to have a greater predisposition to develop an abnormal pH decline (Gerrard, 1997). Muscles considered to be PSE generally have lower pH values and higher muscle temperatures at 40 minutes postmortem (Briskey et al., 1959). Despite an abundance of research describing PSE pork characteristics, and a reduction in the frequency of major genes with known deleterious effects on pork quality, Cassens (2000) concluded that little progress has been made in reducing the incidence of PSE pork.
LITERATURE CITED


CHAPTER 3.
LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON TRANSPORTATION AND PACKING PLANT LOSSES

ABSTRACT: Pig mortalities from the farm to the harvest facility have been estimated to cost the U.S. swine industry between 50 - 100 million dollars annually (Ellis et al., 2003). The objective of this study was to determine if loading system affects the incidence of dead, injured, or stressed pigs during transportation or at the packing plant. Data from a total of 551 semi loads of crossbred pigs from a single commercial finishing site were collected in the Midwest from July, 2006 to October, 2007. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in two different experiments. Experiment one (n=211 semi loads, Mean BW = 116.6 ± 5.4 kg) included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs). Experiment two (n=340 semi loads, Mean BW = 118.5 ± 6.1 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs). Pigs were loaded using an internally-approved Swine Welfare Assurance Program™ (SWAP+) market load assessment, which combines the National Pork Board’s SWAP program and the American Meat Institute’s Animal Handling Audit. This assessment included facility evaluation (chute angle and cleat spacing), adherence to the integrator market pig loading standard operating procedure and transportation standard operating procedure (density and environmental management). Performance measures evaluated were stressed on arrival (SOA), crippled on arrival (COA), dead on arrival (DOA), stressed in plant (SIP), crippled in plant (CIP), and dead in plant (DIP). Stressed (SOA and SIP) pigs were defined “as having
temporarily lost the ability to walk, but had a reasonable expectation to recover full locomotion with rest.” Crippled (COA and CIP) pigs were defined as “any pig that had received an injury that impeded its movement.” Dead (DOA and DIP) pigs were defined as “a pig that had ceased to breathe.” In this study, loading system influenced the incidence of total number of dead pigs ($P < 0.06$) and total losses ($P < 0.03$) in FP pigs. However, loading system does not appear ($P > 0.05$) to play an integral role in the incidence of all other performance measures collected on both FP and CO pigs during transportation and at the packing plant.

**Key words:** finisher pig, loading gantry, welfare

**INTRODUCTION**

Pig mortalities from the farm to the harvest facility have been estimated to cost the U.S. swine industry over $50-100 million dollars annually (Ellis et al., 2003). Subsequently, improved understanding of the major management factors impacting behavioral and physiological responses of the finisher pig during transportation is needed. Animal “movement is accomplished by making the target location, or route to it, more attractive than the starting location” (Gonyou, 1993). Pigs are motivated by several factors including natural curiosity, odors, sounds, food, water, and fear (McGlone et al., 2004).

Consumers, public and private agencies, livestock producers, and research scientists have shown an increasing interest in assuring proper animal care and handling (Von Borell et al., 2005). In 2004, a group of swine well-being experts that included researchers reviewed the scientific literature pertaining to the fatigued and finisher pig transportation. The researchers and allied industry representatives concluded transport
losses may be influenced by numerous factors including genetics, carcass muscling, health status, structural soundness, body weight, nutrition, handling, facility design, and conditions during transport to the plant (Ritter et al., 2005). Based on several field studies, the incidence of transport losses in market-weight pigs is approximately 1% (Ellis et al., 2003; Ritter et al., 2006). These factors can be stressful for any size and type of pig, and may cause significant changes in the physiology and behavior, and consequently, negatively impact performance and meat quality. Researchers also challenged the industry to “improve finisher pig well-being at the time of marketing” through scientific research on facility design (Ritter et al., 2005).

The goal of any handling and loading system should be to provide a continuous unidirectional flow of pigs from the pen to the trailer, with minimal amount of stress on the animal. Little objective guidance has been available on the optimum design of loading systems. Handling and loading activities have relied heavily on negative motivators or repulsive forces to move the animal (Grandin, 1997). The objective of this study was to determine if loading system affects the incidence of dead, injured, or stressed pigs during transportation or at the packing plant.

**MATERIALS AND METHODS**

**Experimental Design and Treatments**

The protocol for this experiment was approved by the Iowa State University Institutional Animal Care and Use Committee. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in two different experiments. A total of 551 loads of crossbred pigs from a single commercial site were collected at a finishing unit in the Midwest from July, 2006 to October, 2007. Experiment one (n=211 loads,
average number of pigs/load = 167.3, average weight/head = 116.6 ± 5.4 kg) included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs). Experiment two (n=340 loads, average number of pigs/load = 164.4, average weight/head = 118.4 ± 6.0 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs).

**Animals, Farms, and Pig Handling**

Finisher pigs (barrows and gilts) from the progeny of PIC sires and Genetiporc females were used. The farm utilized wean-to-finish buildings and pigs were raised in mixed-sex pens. Each barn was environmentally controlled, utilizing a tunnel ventilation system with double pleated non-insulated curtains for emergency ventilation. Flooring was fully slatted and manure was collected in pits below and mechanically removed. Within each barn there were 48 pens housing approximately 24 pigs per pen. Pigs at first pull were provided 0.59 m$^2$ and at closeout 0.65 m$^2$ per pig.

Pigs were provided ad libitum access to corn-soybean meal diets that met or exceeded National Research Council (NRC) requirements for pigs at various phases of the wean-to-finish production cycle (NRC, 1998). Pigs had continual access to water through a stationary nipple drinker system. Pigs in the first pull were not fed Paylean™ and CO pigs received Paylean™ prior to marketing. Pigs were handled using an internally-approved Swine Welfare Assurance Program™ (SWAP+) market load assessment, which combined the National Pork Board’s SWAP program (NPB, 2003) and the American Meat Institute’s Animal Handling Audit (AMI, 2005). This assessment included facility evaluation (chute angle and cleat spacing), adherence to the market pig loading standard operating procedure, and transportation standard operating procedure.
A single load out crew (n = 5) was responsible for loading all pigs used in the experiment. The loadout crew received formal classroom and on site training by the company to move and handle finisher pigs in a humane manner. This formal training specified movement in groups of four to six finisher pigs from the pens where they were housed to the trailer used to transport animals to the harvest facility.

**Loading System Design**

Two loading system designs were compared in the study. The first loading system design (T) was the company’s traditional metal covered chute. The chute was 76.2 cm wide, 2.3 m high, and 4.6 m in length and used square stock (2.5 cm) metal cleats which were spaced 20.3 cm apart. The T chute included a flat pivot section on each end to accommodate the angle that the trailers were positioned relative to the finishing facility. The angle of the ramp used to load the pigs onto the trailer was approximately 19 degrees to the bottom deck. The trailer included an internal ramp that raised to 23 degrees for access to the upper deck. One incandescent lamp fixture (60 watts) was placed at the entrance to the T chute.

The second design (P) used was a prototype loading gantry (Figure 1.5) aluminum covered chute. The chute was 91.4 cm wide, 3.1 m high, and 9 m in length. The flooring material consisted of metal coated with epoxy (designed to mimic the feel of concrete) and had a stair step design with cleats 2.5 cm in height and spaced 20.3 cm apart. The ramp incline was approximately 7 degrees to the bottom deck and 18 degrees to the upper deck of the trailer. The P chute utilized a lighting system that minimized shadowing. A bumper dock system was incorporated into the chute design to completely eliminate gaps...
from the barn to the chute. The P chute had an extending system that allowed for proper positioning to both the barn and trailer. An electric jack screw system mechanically raised and lowered the P chute into proper position. To protect the integrity of the chute design, all innovative designs and technologies utilized are protected by the U.S. patent system.

**Truck and Transportation**

After loading was complete, pigs were transported approximately 88.5 km or 1 h of travel time to a commercial packing plant. All animal transport procedures complied with the Trucker Quality Assurance Program™ (NPB, 2003). All transport trailers were 16.5 m in length, double deck straight trailers (Barrett Trailers LLC, Purcell, Oklahoma; Wilson Livestock Trailers, Sioux City, IA). All trailers utilized natural ventilation with punched sides and flooring was diamond plate.

**Performance Measurements**

At the plant, trained and certified personnel unloaded the trailers utilizing docks specifically designed to allow an unimpeded pathway for the pigs from both the upper and lower decks. The trailer side door (2.74 m in width) opened and the receiving dock extended outwards to the truck allowing the pigs to walk straight off the trailer and into the receiving area. Crippled, stressed, and dead pigs were counted at two distinct points; first, when unloading was completed and second, during lairage. Performance measures evaluated at the completion of unloading were crippled on arrival (COA), stressed on arrival (SOA), and dead on arrival (DOA). Performance measures evaluated in lairage were crippled in plant (CIP), stressed in plant (SIP), and dead in plant (DIP). Crippled (COA and CIP) pigs were defined as “any pig that had received an injury that impeded its
movement.” Stressed (SOA and SIP) pigs were defined “as having temporarily lost the
ability to walk, but had a reasonable expectation to recover full locomotion with rest.”
Dead (DOA and DIP) pigs were defined as “a pig that had ceased to breathe.” Unloading
and lairage defects were summed to evaluate total crippled, total stressed, total dead, and
total losses.

**Statistical Analysis**

Due to the fact that dependent variables consisted of observational count
(frequencies) data, residual diagnostic checks showed that all dependent variables
violated the normality assumptions of ANOVA. All dependent variables were analyzed
with the use of PROC GLIMMIX in SAS (SAS Inst., Cary, NC) and data had a poisson
distribution. Fixed effects of chute (traditional or prototype), date, month, barn (8
classes), and complex (17 classes) were fitted along with a random effect of date nested
within complex. A linear covariate for number of pigs shipped per load was included in
the analysis model.

The above model is the result of a stepwise process of fitting all 2-way
interactions between fixed effects along with second and third order polynomial effects of
each covariate and removing nonsignificant ($P > 0.05$) individual effects sequentially.
Additional fixed effects of hauler (trucking firm), driver, and load type (all pigs loaded
from the same barn or loaded from two separate barns) along with covariates of load time
(time required to complete a load), travel time (time elapsed from the farm to plant), and
wait to unload time (time elapsed between arrival at the plant and unloading of pigs) were
tested and found not to describe a significant amount of variation for each dependent
variable.
RESULTS AND DISCUSSION

On average, times for travel to the plant and wait to unload at the plant were similar regardless of chute type used or pull at marketing (Table 2.1). However, load time at the finishing facility was higher for all FP pigs and all pigs loaded using the P chute. The increase in load time for FP pigs can be attributed to the extra time required by caretakers to sort pigs out of their home pen. Additionally, the added load time associated with the P chute can be attributed to realignment of the truck and trailer between loading the upper and lower decks.

The average number of pigs shipped per load was higher on loads using the P chute. This difference is due to additional space gained by eliminating the use of the internal ramp when the P chute is utilized. Live weights ranged from 101.2 to 132.7 kg for individual loads collected (Table 2.1).

Experiment one – first pull

Loading system influenced the total number of dead pigs ($P < 0.06$) and total losses ($P < 0.03$, Table 2.2). However, there were no loading system ($P > 0.05$) differences in the incidence of all other performance measures collected (Table 2.2).

Ritter et al. (2006) also reported total losses of 1.08%, and these data were similar to results from a number of other field studies (Ellis et al., 2003; Hambrecht et al., 2004). The current trial is in agreement with previous studies when the T system is used to load pigs ($1.61 \pm 0.18 \text{ pigs/load [0.96%]}$). However, there were fewer total losses reported when pigs were loaded using the P system ($1.15 \pm 0.15 \text{ pigs/load [0.69%]}$).
**Experiment two – closeout pull**

Loading system had no (P > 0.05) influence on performance measures evaluated (Table 2.3). However, reported total losses (1.19 ± 0.15 pigs/load, [0.72%], T vs 0.99 ± 0.15 pigs/load, [0.60%], P) in this study were lower compared to a number of other field studies (Ellis et al., 2003; Hambrecht et al., 2004).

In conclusion, transportation of the finisher pig to market is a critical time period in regards to performance (Rademacher and Davies, 2005). In specific situations, performance and thus economic implications can be manipulated by loading system.

**IMPLICATIONS**

This investigation has provided insight to changes in facility design that may ultimately lead to the minimization of some stressors that pigs are exposed to at the time of marketing. Results indicate that pigs loaded on the P chute during the FP have fewer total deads and total losses.

**LITERATURE CITED**


Table 2.1. Descriptive statistics for load size, average pig live weight, and transportation factors for 85,457 pigs transported in 551 loads

<table>
<thead>
<tr>
<th>Item^b</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD^1</td>
</tr>
<tr>
<td>First pull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. load size</td>
<td>166.1</td>
<td>4.3</td>
</tr>
<tr>
<td>Avg. pig live wt, kg</td>
<td>117.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Avg. load time per pig, min</td>
<td>0.25</td>
<td>0.05</td>
</tr>
<tr>
<td>Travel time, min</td>
<td>64</td>
<td>9</td>
</tr>
<tr>
<td>Wait time, min</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Closeout pull</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg. load size</td>
<td>162.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Avg. pig live wt, kg</td>
<td>118.3</td>
<td>5.9</td>
</tr>
<tr>
<td>Avg. load time per pig, min</td>
<td>0.23</td>
<td>0.06</td>
</tr>
<tr>
<td>Travel time, min</td>
<td>63</td>
<td>8</td>
</tr>
<tr>
<td>Wait time, min</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

^a T = Traditional chute; P = Prototype loading gantry.
^b First pull = first pigs marketed from a finishing facility; Closeout pull = last pigs marketed from a finishing facility; Avg. load size = average number of pigs marketed per load; Avg. pig live wt, kg = average live weight of the entire load; Load time per pig = amount of time required to load each individual pig onto the trailer; Travel time = amount of time required to travel from the finishing site to the plant; Wait time = amount of time lapsed while waiting to unload at the plant.
Table 2.2. Performance measures evaluated on two different loading systems when first pull pigs were marketed

<table>
<thead>
<tr>
<th>Item(^b)</th>
<th>Chute Type(^a)</th>
<th>(T)</th>
<th>(P)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>COA</td>
<td></td>
<td>0.05 ± 0.02</td>
<td>0.02 ± 0.02</td>
<td>0.33</td>
</tr>
<tr>
<td>SOA</td>
<td></td>
<td>0.62 ± 0.10</td>
<td>0.48 ± 0.09</td>
<td>0.29</td>
</tr>
<tr>
<td>DOA</td>
<td></td>
<td>0.33 ± 0.07</td>
<td>0.21 ± 0.05</td>
<td>0.16</td>
</tr>
<tr>
<td>CIP</td>
<td></td>
<td>0.01 ± 0.01</td>
<td>0.00 ± 0.00</td>
<td>0.58</td>
</tr>
<tr>
<td>SIP</td>
<td></td>
<td>0.28 ± 0.06</td>
<td>0.24 ± 0.06</td>
<td>0.59</td>
</tr>
<tr>
<td>DIP</td>
<td></td>
<td>0.31 ± 0.05</td>
<td>0.19 ± 0.05</td>
<td>0.37</td>
</tr>
<tr>
<td>T crippled</td>
<td></td>
<td>0.06 ± 0.06</td>
<td>0.02 ± 0.02</td>
<td>0.27</td>
</tr>
<tr>
<td>T stressed</td>
<td></td>
<td>0.93 ± 0.13</td>
<td>0.73 ± 0.11</td>
<td>0.23</td>
</tr>
<tr>
<td>T dead</td>
<td></td>
<td>0.64 ± 0.09</td>
<td>0.42 ± 0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>T losses</td>
<td></td>
<td>1.61 ± 0.18</td>
<td>1.15 ± 0.15</td>
<td>0.03</td>
</tr>
</tbody>
</table>

\(^a\)T = Traditional chute; P = Prototype loading gantry.

\(^b\)COA = Crippled on arrival; SOA = Stressed on arrival; DOA = Dead on arrival; CIP = Crippled in plant; SIP = Stressed in plant; DIP = Dead in plant; T crippled = Total crippled; T stressed = Total stressed; T dead = Total dead; T losses = Total losses.

\(^1\)First pull = first pigs marketed from a finishing system.
Table 2.3. Performance measures evaluated on two different loading systems when closeout pull pigs were marketed

<table>
<thead>
<tr>
<th>Item</th>
<th>Chute Type(^a)</th>
<th>T</th>
<th>P</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>COA</td>
<td></td>
<td>0.02 ± 0.01</td>
<td>0.01 ± 0.01</td>
<td>0.41</td>
</tr>
<tr>
<td>SOA</td>
<td></td>
<td>0.62 ± 0.10</td>
<td>0.48 ± 0.09</td>
<td>0.19</td>
</tr>
<tr>
<td>DOA</td>
<td></td>
<td>0.18 ± 0.03</td>
<td>0.17 ± 0.04</td>
<td>0.86</td>
</tr>
<tr>
<td>CIP</td>
<td></td>
<td>0.03 ± 0.01</td>
<td>0.00 ± 0.00</td>
<td>0.11</td>
</tr>
<tr>
<td>SIP</td>
<td></td>
<td>0.19 ± 0.04</td>
<td>0.20 ± 0.05</td>
<td>0.86</td>
</tr>
<tr>
<td>DIP</td>
<td></td>
<td>0.17 ± 0.04</td>
<td>0.13 ± 0.04</td>
<td>0.49</td>
</tr>
<tr>
<td>T crippled</td>
<td></td>
<td>0.05 ± 0.02</td>
<td>0.01 ± 0.01</td>
<td>0.06</td>
</tr>
<tr>
<td>T stressed</td>
<td></td>
<td>0.80 ± 0.11</td>
<td>0.67 ± 0.11</td>
<td>0.29</td>
</tr>
<tr>
<td>T dead</td>
<td></td>
<td>0.36 ± 0.06</td>
<td>0.33 ± 0.07</td>
<td>0.74</td>
</tr>
<tr>
<td>T losses</td>
<td></td>
<td>1.19 ± 0.15</td>
<td>0.99 ± 0.15</td>
<td>0.21</td>
</tr>
</tbody>
</table>

\(^a\)T = Traditional chute; P = Prototype loading gantry.

\(^b\)COA = Crippled on arrival; SOA = Stressed on arrival; DOA = Dead on arrival; CIP = Crippled in plant; SIP = Stressed in plant; DIP = Dead in plant; T crippled = Total crippled; T stressed = Total stressed; T dead = Total dead; T losses = Total losses.

\(^1\)Closeout pull = last pigs marketed from a finishing system.
CHAPTER 4.
LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON HANDLING AND WELFARE PARAMETERS AT THE TIME OF MARKETING

ABSTRACT: Marketing and transportation stress not only costs the industry due to mortalities, but has direct impact on the quality of pork delivered to the consumer (Barton-Gade, 1992; Geverink et al., 1996; Hambrecht et al., 2005). The objective of this study was to determine if loading system affects the welfare parameters of pigs at the time of marketing. Data from a total of 74 loads of crossbred pigs from a single finishing site were collected on a commercial finishing unit in the Midwest from November, 2006 to August, 2007. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in two different experiments. Experiment one (n=44 semi loads, Mean BW = 118.9 ± 6.1 kg) included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs). Experiment two (n=30 semi loads, Mean BW = 117.6 ± 5.7 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs). Pigs were loaded using an internally-approved Swine Welfare Assurance Program™ (SWAP+) market load assessment, which combines the National Pork Board’s SWAP program and the American Meat Institute’s Animal Handling Audit. This assessment included facility evaluation (chute angle and cleat spacing), adherence to the integrator market pig loading standard operating procedure, and transportation standard operating procedure (density and environmental management). Welfare parameters evaluated were electric prod use, slips, falls, vocalizations, and piling. Arbitrary definitions for welfare parameters were developed. Electric prod use was any time the prod touched the pig. Slips were instances
in which normal mechanics of gait were interrupted. Falls were imbalances resulting in contact between a non-limb portion of the body and the ground. Vocalizations were characterized as short, loud sounds attributable to individual pigs that could be distinguished from the baseline noises of the group. Piling occurred when one or more pigs had either front or rear feet off the ground and on another pig. Welfare parameters were collected on animals only while they were in the loading system after exiting the barn and prior to entering the trailer. In this study, loading system does influence welfare parameters \((P < 0.01)\) of both FP and CO pigs at the time of marketing. Pigs loaded on the P chute experienced significantly fewer electric prods, slips, falls, vocalizations, and pile ups, regardless of pull at marketing.

**Key words:** finisher pig, handling, loading gantry, welfare

**INTRODUCTION**

Pigs are motivated to move by several factors including natural curiosity, odors, sounds, food, water, and fear (McGlone et al., 2004). During handling and marketing, the pork industry is forced to rely heavily on negative motivators or repulsive forces to move the animal (Hemsworth, 2003). The goal of any handling and loading system should be to provide a continuous unidirectional pig flow from the pen to the trailer, with minimal amount of stress on the animal. Based on several field studies, the incidence of transport losses in market-weight pigs is approximately 1% (Ellis et al., 2003). At the farm, major factors impacting behavioral and physiological responses of the pig during transport include genetics, slaughter weight, environmental conditions (temperature and humidity), health status, marketing strategy, time off feed, pre-transport experiences, facility design, and nature of handling during loading (Ritter et al., 2005).
We were unable to find any research to quantify the economic impact of poor handling and transportation for the employee. Over one-third of employee injuries within finishing operations are animal handling related, of which a majority are due to sorting and loadout procedures (Hill et al., 2007a). In addition, the specialized practices necessary to ensure the well-being of the fatigued pig during unloading and within the processing facility are physically challenging to plant personnel.

The majority of processors are now not only charging the cost of a dead on arrival (DOA) pig back to the producer, but are also charging the cost for an animal received in a compromised state, regardless of whether it is processed for consumption or rendered as a byproduct. In addition, many processors are charging a fee to offset the extra labor cost, loss in efficiencies, and liability associated with handling compromised pigs (Hill et al., 2007a). We have ethical obligations and moral responsibilities to animals under our care, and to consumers trusting the pork industry to produce, transport, and process pigs in a humane manner. The objective of this study was to determine if loading system affects the welfare parameters of pigs at the time of marketing.

MATERIALS AND METHODS

Experimental Design and Treatments

The protocol for this experiment was approved by the Iowa State University Institutional Animal Care and Use Committee. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in two different experiments. A total of 74 loads of crossbred pigs from a single commercial finishing system were evaluated in the Midwest from November, 2006 to August, 2007. Experiment one (n=44 semi loads, average number of pigs/load = 165.9, average weight/head = 118.9 ± 6.1 kg)
included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs). Experiment two (n=30 semi loads, average number of pigs/load = 161.8, average weight/head = 117.6 ± 5.7 g) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs).

**Animals, Farms, and Pig Handling**

Finisher pigs (barrows and gilts) from the progeny of PIC sires and Genetiporc females were used. The farm utilized wean-to-finish buildings and pigs were raised in mixed-sex pens. Each barn was environmentally controlled, utilizing a tunnel ventilation system with double pleated non-insulated curtains for emergency ventilation. Flooring was fully slatted and manure was collected in pits below and mechanically removed. Within each barn there were 48 pens housing approximately 24 pigs per pen. Pigs at first pull were provided 0.59 m² and at closeout 0.65 m² per pig.

Pigs were provided ad libitum access to corn-soybean meal diets that met or exceeded National Research Council (NRC) requirements for pigs at various phases of the wean-to-finish production cycle (NRC, 1998). Pigs had continual access to water through a stationary nipple drinker system. Pigs in the first pull were not fed Paylean™ and CO pigs received Paylean™ prior to marketing. Pigs were handled using an internally-approved Swine Welfare Assurance Program™ (SWAP+) market load assessment, which combined the National Pork Board’s SWAP program (NPB, 2003) and the American Meat Institute’s Animal Handling Audit (AMI, 2005). This assessment included facility evaluation (chute angle and cleat spacing), adherence to the market pig loading standard operating procedure, and transportation standard operating procedure.
(density and environmental management). A single loadout crew (n = 5) was responsible for loading all pigs used in the experiment. The loadout crew received formal classroom and on site training by the company to move and handle finisher pigs in a humane manner. This formal training specified movement in groups of four to six finisher pigs from the pens where they were housed to the trailer used to transport animals to the harvest facility.

**Loading System Design**

Two loading system designs were compared in the study. The first loading system design (T) was the company’s traditional metal covered chute. The chute was 76.2 cm wide, 2.3 m high, and 4.6 m in length and used square stock (2.5 cm) metal cleats which were spaced 20.3 cm apart. The T chute included a flat pivot section on each end to accommodate the angle that the trailers were positioned relative to the finishing facility. The angle of the ramp used to load the pigs onto the trailer was approximately 19 degrees to the bottom deck. The trailer included an internal ramp that raised to 23 degrees for access to the upper deck. One incandescent lamp fixture (60 watts) was placed at the entrance to the T chute.

The second design (P) used was a prototype loading gantry (Figure 1.5) aluminum covered chute. The chute was 91.4 cm wide, 3.1 m high, and 9 m in length. The flooring material consisted of metal coated with epoxy (designed to mimic the feel of concrete) and had a stair step design with cleats 2.5 cm in height and spaced 20.3 cm apart. The ramp incline was approximately 7 degrees to the bottom deck and 18 degrees to the upper deck of the trailer. The P chute utilized a lighting system that minimized shadowing. A bumper dock system was incorporated into the chute design to completely eliminate gaps
from the barn to the chute. The P chute had an extending system that allowed for proper
classification to both the barn and trailer. An electric jack screw system mechanically
raised and lowered the P chute into proper position. To protect the integrity of the chute
design, all innovative designs and technologies utilized are protected by the U.S. patent
system.

**Truck and Transportation**

After loading was complete, pigs were transported approximately 88.5 km or 1 h
of travel time to a commercial packing plant. All animal transport procedures complied
with the Trucker Quality Assurance Program™ (NPB, 2003). All transport trailers were
16.5 m in length, double deck straight trailers (Barrett Trailers LLC, Purcell, Oklahoma;
Wilson Livestock Trailers, Sioux City, IA). All trailers utilized natural ventilation with
punched sides and flooring was diamond plate.

**Welfare Parameters**

Welfare parameters were evaluated on pigs while in the loading system after
exiting the barn and prior to entering the trailer. Welfare parameters evaluated were
electric prod use, slips, falls, vocalizations, and piling. Arbitrary definitions for welfare
parameters were developed. Electric prod use was any time the prod touched the pig.
Slips were instances in which normal mechanics of gait were interrupted. Falls were
imbalances resulting in contact between a non-limb portion of the body and the ground.
Vocalizations were characterized as short, loud sounds attributable to individual pigs that
could be distinguished from the baseline noises of the group. Piling occurred when one
or more pigs had either front or rear feet off the ground and on another pig.
Statistical Analysis

All dependent variables were analyzed using PROC MIXED of SAS (SAS Inst., Cary, NC). Fixed effects of chute (traditional or prototype), load number (number of loads in a given night, 6 classes), date, month, barn (8 classes), and complex (17 classes) were fitted along with a random effect of date nested within complex in all analysis models. A linear covariate of number of pigs shipped per load was included in the model.

RESULTS AND DISCUSSION

Experiment one – first pull

Loading system influenced all welfare parameters \( P < 0.01 \) at the time of marketing (Table 3.1). Pigs loaded on the P chute experienced fewer electric prods, slips, falls, vocalizations, and pile ups.

Experiment two – closeout pull

Loading system influenced all welfare parameters \( P < 0.01 \) at the time of marketing (Table 3.2). Pigs loaded on the P chute experienced fewer electric prods, slips, falls, vocalizations, and pile ups.

A previous study by McGlone (2005) demonstrated that the use of electric prods increased the time required for movement, resulting in approximately 15% of the pigs to “jump” when the electric prod was applied, significantly increased vocalizations, and caused a greater number of fatigued pigs received at the plant. If regular use of an electric prod is needed, the adequacy of the handling facilities should be examined (Grandin et al., 1998; Grandin, 2006). If a pig is prodded several times in rapid succession its heart rate, body temperature, incidence of open mouth breathing, and blood
lactate levels will increase significantly, indicating that the pig is experiencing a
stressor(s), which in turn can affect their well-being (Grandin, 1993).

The greatest limitation on retrospective observational studies of transport deaths is
the lack of data on handling intensity. Several experimental studies have evaluated the
effects of handling intensity on blood chemistry (Hemsworth et al., 1993; Hamilton et al.,
2004; Bertol et al., 2005; Ellis and Ritter, 2005). Under experimental conditions with
animals moving at their own pace, nominal effects on acid-base measures were observed,
while aggressively handled pigs became acidic and fatigued.

In conclusion, the T loading system in the current study is associated with more
intensive handling at the time of marketing as defined by an increased incidence in prods,
slips, falls, vocalizations, and pile ups when loaded. Ultimately, this demonstrates that
the implementation of the P chute in this system made it possible to minimize the stress
placed on market pigs at loadout. Understanding key factors influencing losses during
this time frame enables targeted interventions to improve both welfare and profitability.

**IMPLICATIONS**

This investigation has provided data to support changes in facility design that may
ultimately lead to the minimization of some stressors that pigs are exposed to at the time
of marketing. Results indicate that pigs loaded on the P chute experienced fewer prods,
slips, falls, vocalizations, and pile ups.

**LITERATURE CITED**

American Meat Institute. 2005. Recommended animal handling guidelines and audit


Table 3.1. Subjective welfare parameters from a study evaluating two different loading systems when first pull pigs were marketed.  

<table>
<thead>
<tr>
<th>Item</th>
<th>Chute Type&lt;sup&gt;a&lt;/sup&gt;</th>
<th>T</th>
<th>P</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric prods</td>
<td>161.59 ± 14.05</td>
<td>96.25 ± 12.86</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Slips</td>
<td>247.91 ± 20.53</td>
<td>96.02 ± 18.93</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>100.42 ± 9.14</td>
<td>20.18 ± 8.34</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Vocalizations</td>
<td>138.06 ± 12.12</td>
<td>69.08 ± 11.10</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Pile ups</td>
<td>3.59 ± 0.48</td>
<td>0.01 ± 0.47</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>T = Traditional chute; P = Prototype loading gantry  
<sup>b</sup>Electric prods = any time the prod touched the pig; Slips = instances where normal mechanics of gait were interrupted; Falls = imbalances resulting in contact between a non-limb portion of the body and the ground; Vocalizations = characterizations of short, loud sounds attributable to individual pigs that could be distinguished from the baseline noises of the group; Pile ups = one or more pigs had either front or rear feet off the ground and on another animal.  
<sup>1</sup>Welfare parameters = measurements (electric prods, slips, falls, vocalizations and pile ups) collected on pigs in the loading system; First pull = first pigs marketed from a finishing system.
**Table 3.2.** Subjective welfare parameters from a study evaluating two different loading systems when closeout pull pigs were marketed

<table>
<thead>
<tr>
<th>Item</th>
<th>Chute Type&lt;sup&gt;a&lt;/sup&gt;</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>P</td>
<td>P-value</td>
<td></td>
</tr>
<tr>
<td>Electric prods</td>
<td>188.23 ± 10.50</td>
<td>108.12 ± 12.86</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Slips</td>
<td>302.48 ± 23.22</td>
<td>106.02 ± 25.74</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Falls</td>
<td>115.37 ± 13.93</td>
<td>24.75 ± 15.65</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>Vocalizations</td>
<td>140.44 ± 7.64</td>
<td>79.21 ± 9.40</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>Pile ups</td>
<td>4.63 ± 0.39</td>
<td>0.10 ± 0.47</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>T = Traditional chute; P = Prototype loading gantry  
<sup>b</sup>Electric prods = any time the prod touched the pig; Slips = instances where normal mechanics of gait were interrupted; Falls = imbalances resulting in contact between a non-limb portion of the body and the ground; Vocalizations = characterizations of short, loud sounds attributable to individual pigs that could be distinguished from the baseline noises of the group; Pile ups = one or more pigs had either front or rear feet off the ground and on another animal.  
<sup>1</sup>Welfare parameters = measurements (electric prods, slips, falls, vocalizations and pile ups) collected on pigs in the loading system; Closeout pull = last pigs marketed from a finishing system.
CHAPTER 5.
LOADING GANTRY VERSUS TRADITIONAL CHUTE FOR THE FINISHER PIG: EFFECT ON MEAT QUALITY ATTRIBUTES

ABSTRACT: Economic losses associated with pigs that die or become fatigued during transportation and at the packing plant, as well as the negative attributes associated with poor meat quality, have been estimated to cost the U.S. swine industry $300-350 million dollars annually (Ellis et al., 2003; Stetzer and McKeith, 2003). The objective of this study was to determine if loading system affects pork quality attributes. Data from a total of 6 loads of crossbred pigs (n=992) from a single commercial finishing site in the Midwest were collected from January, 2007 to February, 2007. A random sample of pigs (n=630) were chosen for meat quality evaluation. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in three different experiments. Experiment one (n=2 semi loads, Mean BW = 111.7 ± 1.9 kg) included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs). Experiment two (n=2 semi loads, Mean BW = 131.5 ± 1.7 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO]) pigs). Experiment three (n=2 semi loads, Mean BW = 114.9 ± 4.8 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO]) pigs). Meat quality attributes evaluated were initial pH, 24 h pH, Japanese color score (JCS) of the cut surface, JCS of the rib surface, and loin L*. All meat quality attributes were collected from the longissimus dorsi (LD). Initial pH (~35 min postmortem) was measured on the LD at the last rib of each carcass. Measurements were collected on line prior to carcasses entering the blast chill. A 24 h pH
was determined at the same location. Both pH measures were collected using a Hanna 9025 pH/ORP meter (Hanna Instruments, Woonsocket, RI), which was calibrated at the expected temperature of the carcasses. Carcasses remained in the cooler until 24 h postmortem, at which time they were fabricated and further sampling was performed.

The 24 h pH, objective (CIE L*), and subjective (JCS cut and JCS rib) color measurements were determined on the LD of the selected carcasses by highly trained experienced personnel. Objective color (CIE L*) measurements were obtained from a cross-section of the loin between the 10th and 11th rib. Color was determined using a Minolta CR-400 Chroma Meter with illuminant C and 20 standard observer. Color was also evaluated using the JCS system consisting of six plastic discs that ranged from scores of 1 to 6 (1=pale grey, 6=dark purple). Japanese color scores (JCS rib) were estimated on the outer surface (lean) of the LD and on the cross-section (JCS cut) of the loin between the 10th and 11th rib. In this study, loading system did influence several meat quality attributes evaluated. In experiment one, loins from pigs loaded with the P loading system had higher \( P < 0.05 \) initial and 24 h pH and tended to have higher \( P = 0.08 \) JCS cut values, but lower \( P = 0.03 \) loin L* values. In experiment two, loins from pigs loaded with the P loading system had higher \( P = 0.01 \) 24 h pH and JCS rib values. Pigs loaded on the P loading system had lower \( P = 0.06 \) L* values. Additionally, in experiment three, loins from pigs loaded with the T loading system had higher \( P = 0.01 \) initial pH and higher \( P = 0.03 \) 24 h pH values. Pigs loaded on the T loading system also had higher \( P = 0.01 \) JCS cut scores, higher \( P = 0.02 \) JCS rib scores, and lower \( P = 0.01 \) L* values.

Key words: finisher pig, loading gantry, meat quality
INTRODUCTION

The swine industry is continually striving to improve animal health and well-being, and to deliver a safe, wholesome, and nutritious product to the consumer. A major factor that can affect the well-being of the finisher pig and final meat quality attributes is implementation of management strategies that promote correct swine handling at the time of marketing.

When swine are moved, negative motivators or repulsive forces to move the animal are often utilized (Hemsworth, 2003). The goal of any handling and loading system should be to provide a continuous unidirectional pig flow from the pen to the trailer, with minimal amount of stress on the animal (Hill et al., 2007b).

The issue of the fatigued pig and the resultant effects on meat quality are multifactorial and follow the additive stressor model proposed by Broom and Johnson (1993) and McFarlane and Curtis (1989). Factors such as the effects of handling intensity on blood chemistry (Ellis and Ritter, 2005; Hamilton et al., 2004; Bertol et al., 2005), stocking densities (Rademacher and Davies, 2005) and the effects of high preslaughter stress (Hambrecht et al., 2004a, b) can all result in an increase in the incidence of the fatigued pig and inferior pork quality. Economic losses associated with pigs that die or become fatigued during transportation and at the packing plant, as well as the negative attributes associated with poor meat quality, have been estimated to cost the U.S. swine industry $300-350 million dollars annually (Ellis et al., 2003; Stetzer and McKeith, 2003).

The objective of this study was to determine if loading system affects pork quality attributes.
MATERIALS AND METHODS

Experimental Design and Treatments

The protocol for this experiment was approved by the Iowa State University Institutional Animal Care and Use Committee. A total of 6 loads (approximately 168 head / load) of crossbred pigs (n=992) from a single commercial finishing site in the Midwest were evaluated from January, 2007 to February, 2007. A random sample of pigs (n=630) were chosen for meat quality evaluation. Two loading systems (prototype loading gantry [P] vs. traditional chute [T]) were compared in three independent experiments.

Experiment one (n = 2 loads, average number of pigs/load = 160, average weight/head = 111.7 ± 1.9 kg) included the comparison of two loading systems on the first pigs marketed from a finishing facility (first pull [FP] pigs).

Experiment two (n = 2 loads, average number of pigs/load = 172, average weight / head = 131.5 ± 1.7 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs).

Experiment three (n = 2 loads, average number of pigs / load = 172, average weight / head = 114.9 ± 4.8 kg) included the comparison of two loading systems on the last pigs marketed from a finishing facility (closeout [CO] pigs).

In experiment three, pigs loaded with the P loading system experienced a delay (~10 min in duration) due to piling during the loadout procedure. At the onset of the study, experiments two and three were intended to comprise the same dataset, but were separated based on circumstantial observations.
Animals, Farms, and Pig Handling

Finisher pigs (barrows and gilts) from the progeny of PIC sires and Genetiporc females were used. The farm utilized wean-to-finish buildings and pigs were raised in mixed-sex pens. Each barn was environmentally controlled, utilizing a tunnel ventilation system with double pleated non-insulated curtains for emergency ventilation. Flooring was fully slatted and manure was collected in pits below and mechanically removed. Within each barn there were 48 pens housing approximately 24 pigs per pen. Pigs at first pull were provided 0.59 m$^2$ and at closeout 0.65 m$^2$ per pig.

Pigs were provided ad libitum access to corn-soybean meal diets that met or exceeded National Research Council (NRC) requirements for pigs at various phases of the wean-to-finish production cycle (NRC, 1998). Pigs had continual access to water through a stationary nipple drinker system. Pigs in the first pull were not fed Paylean™ and CO pigs received Paylean™ prior to marketing. Pigs were handled using an internally-approved Swine Welfare Assurance Program™ (SWAP+) market load assessment, which combined the National Pork Board’s SWAP program (NPB, 2003) and the American Meat Institute’s Animal Handling Audit (AMI, 2005). This assessment included facility evaluation (chute angle and cleat spacing), adherence to the market pig loading standard operating procedure, and transportation standard operating procedure (density and environmental management). A single loadout crew (n = 5) was responsible for loading all pigs used in the experiment. The loadout crew received formal classroom and on site training by the company to move and handle finisher pigs in a humane manner. This formal training specified movement in groups of four to six finisher pigs
from the pens where they were housed to the trailer used to transport animals to the harvest facility.

**Loading System Design**

Two loading system designs were compared in the study. The first loading system design (T) was the company’s traditional metal covered chute. The chute was 76.2 cm wide, 2.3 m high, and 4.6 m in length, and used square stock (2.5 cm) metal cleats which were spaced 20.3 cm apart. The T chute included a flat pivot section on each end to accommodate the angle that the trailers were positioned relative to the finishing facility. The angle of the ramp used to load the pigs onto the trailer was approximately 19 degrees to the bottom deck. The trailer included an internal ramp that raised to 23 degrees for access to the upper deck. One incandescent lamp fixture (60 watts) was placed at the entrance to the T chute.

The second design (P) used was a prototype loading gantry (Figure 1.5) aluminum covered chute. The chute was 91.4 cm wide, 3.1 m high, and 9 m in length. The flooring material consisted of metal coated with epoxy (designed to mimic the feel of concrete) and had a stair step design with cleats 2.5 cm in height and spaced 20.3 cm apart. The ramp incline was approximately 7 degrees to the bottom deck and 18 degrees to the upper deck of the trailer. The P chute utilized a lighting system that minimized shadowing. A bumper dock system was incorporated into the chute design to completely eliminate gaps from the barn to the chute. The P chute had an extending system that allowed for proper positioning to both the barn and trailer. An electric jack screw system mechanically raised and lowered the P chute into proper position. To protect the integrity of the chute
design, all innovative designs and technologies utilized are protected by the U.S. patent system.

**Truck and Transportation**

After loading was complete, pigs were transported approximately 88.5 km or 1 h of travel time to a commercial packing plant. All animal transport procedures complied with the Trucker Quality Assurance Program™ (TQA™; NPB, 2003). All transport trailers were 16.5 m in length, double deck straight trailers (Barrett Trailers LLC, Purcell, Oklahoma; Wilson Livestock Trailers, Sioux City, IA). All trailers utilized natural ventilation with punched sides and flooring was diamond plate.

**Processing**

Pigs were harvested at a commercial facility on three separate days (day one = 200 pigs, day two = 240 pigs, day three = 190 pigs). Pigs were held in lairage for an average of 4 h, and food was withheld overnight, however, pigs had continual access to water. A CO$_2$ anesthetizing system was used to immobilize the pigs. The carcasses were held in a blast chiller for a period of 90 min. Following the blast chill, carcasses were held in a conventional cooler until processed the next day.

**Meat Quality Attributes**

Initial pH (~35 min postmortem) was measured at the last rib of the same LD of each carcass prior to entering the blast chill chamber. Additionally, 24 h pH was evaluated on the same muscle and at the same location on the carcass. Both measures were collected using a Hanna 9025 pH/ORP meter (Hanna Instruments, Woonsocket, RI), which was calibrated at the expected temperature of the carcasses. Carcasses remained in
the cooler until 24 h postmortem, after which time they were fabricated and further sampling was performed as described below.

The 24 h pH, objective (CIE L*), and subjective (JCS cut and JCS rib) color measurements were determined on the longissimus dorsi of the selected carcasses by highly trained experienced personnel. Objective color was determined using a Minolta CR-400 Chroma Meter with illuminant C and 20 standard observer. Color measurements (L* values) were taken from a cross-section of the loin between the 10th and 11th rib. Subjective color was evaluated using the JCS system consisting of six plastic discs that ranged from scores of 1 to 6 (1=pale grey, 6=dark purple). Japanese color scores were obtained from the outer surface (lean) of the LD and from the cross-section of the LD between the 10th and 11th rib. Color pass rate was determined utilizing an internally-approved scale used for identification of loins that met specifications for upper-end foreign markets. Methods for collection of meat quality attributes were developed from (Mendez, 2005).

**Statistical Analysis**

All dependent variables (initial pH, 24 h pH, JCS cut score, JCS rib score, color pass rate and loin L*) were analyzed with the use of PROC MIXED in SAS® (SAS Inst., Cary, NC). Fixed effects of chute (traditional or prototype), complex (17 classes) and gender (barrow or gilt) were fitted along with a random effect of date nested within complex.
RESULTS AND DISCUSSION

Experiment one – first pull

Loins from pigs loaded with the P loading system had higher ($P < 0.05$) initial and 24 h pH and tended to have higher ($P = 0.08$) JCS cut values, but lower ($P = 0.03$) loin L* values (Table 4.1). The higher JSC cut values and lower L* values indicate a darker, redder color meat.

Experiment two – closeout pull

Loins from pigs loaded with the P loading system had higher ($P = 0.01$) ultimate pH and JCS rib values. Pigs loaded on the P loading system had lower ($P = 0.06$) L* values. Although not statistically different ($P = 0.14$), pigs loaded with the P loading system had 8% more loins qualify for upper-end foreign markets as evidenced by the color pass rate values (Table 4.2).

Experiment three – closeout pull

Loins from pigs loaded with the T loading system had higher ($P = 0.01$) initial pH and higher ($P = 0.03$) ultimate pH values. Pigs loaded on the T loading system also had higher ($P = 0.01$) JCS cut values, higher ($P = 0.02$) JCS rib scores, and lower ($P = 0.01$) L* values, all indicative of a darker, redder meat. Although not statistically different ($P = 0.07$), pigs loaded with the T loading system had 7% more loins qualify for upper-end foreign markets as evidenced by the color pass rate values (Table 4.3).

In experiment three, the circumstances (delay during loading) noted previously may help explain variation detected between the two loading systems. Additionally, several previous studies (Barton-Gade, 1992; Geverink et al., 1996; Grandin, 1997; Benjamin et al., 2001; Rosenvold and Andersen, 2003; Hamilton et al., 2004; Hambrecht,
provide clarity to the variation observed in experiment three based on the difference in handling intensity.

Novelty can be a profound stressor to pigs, which possess numerous survival responses when confronted by experiences of any nature to which they are unaccustomed (Grandin, 1997). This is especially evident when the novel experience is aversive. Pigs do not habituate well to noxious stimuli. Over time, pigs consider the grow-finish environment in which they have resided for a few months to be their “environmental model”, the place where they feel most comfortable and secure. Of all the potential predisposing factors for development of deleterious meat quality, handling intensity may have the largest impact. Grandin (1997) noted that prods should not be the primary driving aid to move finisher pigs at the time of loading. Pigs moved with electric prods might require more time to recover than pigs moved with other moving devices (i.e., paddle or sort board). It has been reported that pigs moved with electric prods had higher blood lactate and lower blood bicarbonate and base-excess values 2 h after handling (Hamilton et al., 2004). Moving pigs rapidly with electric prods compared to moving pigs at their own pace with a plastic cane increased open-mouth breathing, skin discoloration, heart rate, rectal temperature, and percentage (20% vs. 0%, respectively) of fatigued pigs (Benjamin et al., 2001). Collectively, these studies demonstrate the adverse effects of aggressive handling on changes in blood acid-base status and fatigued pigs at the packing plant.

Marketing and transportation stress not only costs the industry due to pig mortalities, but has direct impact on the quality of pork delivered to the consumer (Barton-Gade, 1992; Geverink et al., 1996; Hambrecht, 2005). With regards to pork
quality, Rosenvold and Andersen (2002) determined that the degree of pre-slaughter stress had a marked effect on muscle temperature early postmortem and pH decline in some pigs which was crucial to color development and color stability. Similarly, Kuchenmeister et al. (2005) concluded that applied stress (5 min before harvest) from an electric prod resulted in an increased heart rate, lower early (0 and 45 min) postmortem pH, higher Minolta L* values, and approximately 2% more drip loss when compared to a nose snare and control (no stress) treatment.

Problems with color have been estimated to cost $0.43 per head, for bruising, $0.08 per head, and for pale, soft, and exudative (PSE) meat, $0.90 per head. This results in a total lost opportunity for the U.S. swine industry of $254,104,500 or $2.44 per finisher head per year (Stetzer and McKeith, 2003). Grandin (1999) reported approximately 10% more pork would be suitable for high quality exports to Japan when pigs are handled quietly and usage of electric prods is reduced. As reported previously (Chapter 3), the implementation of the P chute in this system made it possible to minimize the handling stress placed on market pigs at loadout. Results indicated that pigs loaded on the P chute experience fewer prods, slips, falls, vocalizations, and pile ups. Understanding key factors influencing losses during this time frame enables targeted interventions to improve both welfare and meat quality.

**IMPLICATIONS**

This investigation has provided data to support changes in facility design that may ultimately lead to the improvement of pork quality. Results indicate that pigs loaded on the P chute, under routine management, have superior meat quality attributes. However,
differences in results in this investigation implicate extreme exposure to stressors that occur at the time of marketing may negate advantages that loading system provides.

**LITERATURE CITED**


Table 1. Subjective and objective fresh pork quality attributes from a study evaluating two different loading systems when first pull pigs are marketed\(^1\)

<table>
<thead>
<tr>
<th>Item(^b)</th>
<th>Chute Type(^a)</th>
<th>T</th>
<th>P</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial pH</td>
<td>6.47 ± 0.02</td>
<td>6.53 ± 0.02</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>24 h pH</td>
<td>5.70 ± 0.01</td>
<td>5.74 ± 0.01</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>JCS cut</td>
<td>3.09 ± 0.04</td>
<td>3.20 ± 0.04</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>JCS rib</td>
<td>3.27 ± 0.05</td>
<td>3.19 ± 0.05</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>Color pass rate</td>
<td>100</td>
<td>100</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Loin L*</td>
<td>46.72 ± 0.31</td>
<td>45.74 ± 0.31</td>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)T = Traditional chute; P = Prototype loading gantry

\(^b\)Initial pH = pH measurement collected at 35 minutes postmortem prior to entering chill; 24 h pH = pH measurement collected at 24 hours postmortem; JCS cut = Japanese color score on cut surface; JCS rib = Japanese color score on rib surface; Color pass rate = combination of color scores utilized to determine if loins meet export criteria; Loin L* = measurement of paleness of loin surface.

\(^1\)Fresh pork quality = measurements collected within 24 hours postmortem; First pull = first pigs marketed from a finishing system.
Table 2. Subjective and objective fresh pork quality attributes from a study evaluating two different loading systems when closeout pull pigs are marketed

<table>
<thead>
<tr>
<th>Item</th>
<th>Chute Type&lt;sup&gt;a&lt;/sup&gt;</th>
<th></th>
<th></th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>P</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial pH</td>
<td>6.48 ± 0.03</td>
<td>6.51 ± 0.03</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>24 h pH</td>
<td>5.70 ± 0.01</td>
<td>5.74 ± 0.01</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>JCS cut</td>
<td>3.09 ± 0.04</td>
<td>3.20 ± 0.04</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>JCS rib</td>
<td>3.10 ± 0.04</td>
<td>3.26 ± 0.04</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Color pass rate</td>
<td>77.89 ± 3.94</td>
<td>86.17 ± 3.96</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Loin L*</td>
<td>46.78 ± 0.38</td>
<td>45.76 ± 0.38</td>
<td>0.06</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>T = Traditional chute; P = Prototype loading gantry

<sup>b</sup>Initial pH = pH measurement collected at 35 minutes postmortem prior to entering chill; 24 h pH = pH measurement collected at 24 hours postmortem; JCS cut = Japanese color score on cut surface; JCS rib = Japanese color score on rib surface; Color pass rate = combination of color scores utilized to determine if loins meet export criteria; Loin L* = measurement of paleness of loin surface.

<sup>1</sup>Fresh pork quality = measurements collected within 24 hours postmortem; Closeout pull = last pigs marketed from a finishing system.
Table 3. Subjective and objective fresh pork quality attributes from a study evaluating two different loading systems when closeout pull pigs are marketed\textsuperscript{1}

<table>
<thead>
<tr>
<th>Item\textsuperscript{b}</th>
<th>Chute Type\textsuperscript{a}</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>P</td>
<td>P-value</td>
<td></td>
</tr>
<tr>
<td>Initial pH</td>
<td>6.59 ± 0.02</td>
<td>6.48 ± 0.02</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>24 h pH</td>
<td>5.72 ± 0.01</td>
<td>5.76 ± 0.01</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>JCS cut</td>
<td>3.16 ± 0.04</td>
<td>3.02 ± 0.04</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>JCS rib</td>
<td>3.28 ± 0.04</td>
<td>3.16 ± 0.04</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Color pass rate</td>
<td>85.00 ± 3.61</td>
<td>75.83 ± 3.61</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>Loin L*</td>
<td>45.13 ± 0.34</td>
<td>46.41 ± 0.34</td>
<td>0.01</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}T = Traditional chute; P = Prototype loading gantry

\textsuperscript{b}Initial pH = pH measurement collected at 35 minutes postmortem prior to entering chill; 24 h pH = pH measurement collected at 24 hours postmortem; JCS cut = Japanese color score on cut surface; JCS rib = Japanese color score on rib surface; Color pass rate = combination of color scores utilized to determine if loins meet export criteria; Loin L* = measurement of paleness of loin surface.

\textsuperscript{1}Fresh pork quality = measurements collected within 24 hours postmortem; Closeout pull = last pigs marketed from a finishing system.
CHAPTER 6.

GENERAL SUMMARY

Improved understanding of the major management factors impacting finisher pig behavioral and physiological responses during handling and transportation has recently emerged as an area of concern in the swine industry. Understanding key factors influencing losses during this time frame enables targeted interventions to improve both welfare and profitability.

This investigation has provided insight to changes in facility design that may ultimately lead to the minimization of some stressors that pigs are exposed to at the time of marketing. Results indicate that pigs loaded on the P chute during the FP have fewer total deads and total losses. Pigs loaded on the P chute experience fewer prods, slips, falls, vocalizations, and pile ups. Additionally, results indicate that pigs loaded on the P chute, under routine management, have superior meat quality attributes. However, differences in results in this investigation implicate extreme exposure to stressors that occur at the time of marketing may negate advantages that alternate loading systems provide. The findings from this trial suggest to swine producers that challenges related to solving the fatigued and dead pig phenomenon encompass more issues than just chute design. As an industry we need to be proactive in taking a “whole systems” approach to solving the problem, which may include components of facility design and management.
CHAPTER 7.
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APPENDIX

SUPPLEMENTARY FIGURES

Figure 1.1 Hypothetical continuum of stress for fatigued and dead pigs.

Normal Pig

↓ Stress

Open-mouth Breathing
Skin Discoloration
Pig Refuses to Move

↓ Stress

Abnormal Vocalizations
Muscle Tremors
Collapse = Fatigued

↓ Stress

Death

(Ritter et al., 2005)
Figure 1.2 Additive stressor model. Responses to a series of stimuli which, individually have moderate effects, but can be lethal in combination.

(Broom and Johnson, 2003)
Figure 1.3 Point of balance, blind spot and flight zone for a pig.

(Grandin, 2006)
Figure 1.4 Impact of chute angle on heart rate. (Information based on compilation of previous research)

<table>
<thead>
<tr>
<th>Chute Angle</th>
<th>% increase over normal resting HR*</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>20</td>
<td>Increase due to human interaction/removal from home pen</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>100</td>
<td>Many pigs refuse to attempt ascension (require stimulation)</td>
</tr>
<tr>
<td>35</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>160</td>
<td>Majority of pigs refuse ascension</td>
</tr>
<tr>
<td>50</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>200</td>
<td></td>
</tr>
</tbody>
</table>

Normal Resting Heart Rate (HR*) = 120 bpm for a finisher pig.

(Van Putten and Elshoff, 1978; Mayes and Jesse, 1980; Gonyou, 1993; and McGlone et al., 2004)
Figure 1.5 Schematic drawings of prototype loading gantry.