RAMPED NURSERY HOUSING OF PIGS AND ITS EFFECTS ON BEHAVIOR DURING THE NURSERY PHASE AND DURING TRAILER LOADING AND UNLOADING AT MARKETING

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MASTER OF SCIENCE

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ABSTRACT

Transportation, including semi-trailer loading and unloading, is known to stress pigs in commercial production. Therefore, strategies for reducing stress experienced by pigs during transportation are needed to reduce poor welfare outcomes. The objective of this thesis was to evaluate the effects of early-life exposure to ramps during the nursery phase on ease of loading and unloading at market. Our results indicate that including a ramp in the nursery pen reduces total time taken by market pigs to ascend a loading ramp to a semi-trailer.

Additionally, we were interested in whether inclusion of the ramp in the nursery phase affected nursery behavior and production performance during the nursery and grow-finish phases. Results indicate that ramps in the nursery pen have no effect on behavior and production performance during the nursery period.

These results show that presence of a ramp in the nursery eases loading, doesn't affect pig behavior and growth during the nursery (and) or grow-finish phase. Including a ramp during the nursery phase could mitigate pig stress caused by loading and unloading at marketing.

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DEDICATION

I dedicate this Thesis to my lovely parents, Honorable and Mrs. Richard & Stella Oseku, you have raised and nurtured me into the woman I am today, you have loved me and my siblings beyond comprehension and that love has always kept me going. Thank you for always believing in me. Thank you for being my two greatest cheerleaders.

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LIST OF ABBREVIATIONS

ADFI..Average Daily Feed Intake

ADG...Average Daily Gain

BW...Body Weight

DM...Dry Matter

DOA...Dead on Arrival

FI...Feed Intake

F:G ....Gain to Feed ratio

TQA ....Transport Quality Assurance

1. LITERATURE REVIEW

1.1. Conceptualizing Animal Welfare

Public concern for farm animal welfare has become common in recent decades, as consumers have increasingly expressed a desire to learn more about the food they are consuming. Consumers purchasing animal products based on sustainability and high product quality consider topics such as animal welfare, production systems, and environmental protection issues, among others (Broom, 2010; Delsart et al., 2020). For example, a survey carried out by Grunert et al. (2017) analyzed which production attributes related to environment, health, and animal welfare were considered by consumers when making choices about the purchases of pork in Germany and Poland. The results indicated that 41.5% of German respondents considered animal welfare and free mobility to be the most important production attributes. As a result of increased consumer concern related to animal welfare, a greater emphasis has been placed on understanding what farm animal welfare "is" by livestock stakeholders, animal scientists, and veterinarians in order to improve its measurement on farm.

Animal welfare is defined as "*the state of an individual animal with regard to its attempts to cope with its environment* (Broom, 1986)". Historically, the five freedoms have been used as a conceptual framework for what an animal needs to have good welfare. Their development dates back to 1964, when Ruth Harrison, a British animal activist and writer, wrote a book titled "Animal Machines," which described intensive livestock and poultry farming practices at that time. The book had a profound impact on public opinion and prompted the British government to appoint the Brambell Committee to investigate the welfare of farmed animals. After concluding their investigation, the Brambell Committee reported that animals should have the freedom to "*stand up, lie down, turn around, groom themselves and stretch their limbs* (Singer, 1987).” These Freedoms were redefined in 1979 by the UK’s Farm Animal Welfare Council (FAWC) to reflect their current form. They include: 1) freedom from thirst, hunger and malnutrition, 2) freedom from discomfort, 3) freedom from pain, injury and disease, 4) freedom to express normal behavior, and 5) freedom from fear and distress.

While the Five Freedoms represent ideals for an animal’s welfare, they do not represent a meaningful framework for evaluating an animal’s welfare state using science-based standards for acceptable welfare (FAWC, 2012). Additionally, since the term “*freedom”* implies that each of the Five Freedoms are fully achievable, the Five Freedoms may be misleading to others who do not work directly with animals (Mellor, 2016). To improve upon these drawbacks, Mellor and Reid (1994) introduced the Five Domains Model, which expanded upon the Five Freedoms’ basic principles of animal welfare needs by focusing on both physical and functional animal needs, as well as animal needs related to subjective experience (*i.e.* affect; Mellor, 2016).

1.1.1. The Five Domains Model

The Five Domains Model is a structured, systematic, and comprehensive welfare assessment framework that can be used to identify welfare compromise and facilitate improvement in a range of animal species and contexts (Mellor, 2020). In its original form, it was developed as a tool for assessing welfare compromise of animals used in research, teaching, and testing (Mellor and Reid 1994). However, the model has undergone several updates to best reflect current developments in “animal welfare science thinking,” and has been widely applied to contexts outside of its original intent (Mellor et al., 2020). The model provides a full basis for identifying opportunities to promote positive welfare in intensively farmed animals (Kells, 2022).

The model facilitates identification of internal physical/functional states and external circumstances (Domains 1 - 4) that give rise to negative or positive subjective mental experiences (*i.e.* affects; Domain 5) that have animal welfare significance (Mellor, 2017; **Fig. 1.1**). The first 3 Domains; nutrition, physical environment, and health, focus their attention on the internal states, while Domain 4, behavioral interaction, focuses on welfare-significant external circumstances. In the 2020 version of the Five Domains model, Domain 4 was further modified to include human-animal interactions, which focuses on the impacts of human presence and behavior on the behavioral and affective responses of the animals under their care (Mellor et al., 2020). Together, these four domains negatively or positively affect the fifth affective domain which cannot be measured directly (Mellor et al., 2020).

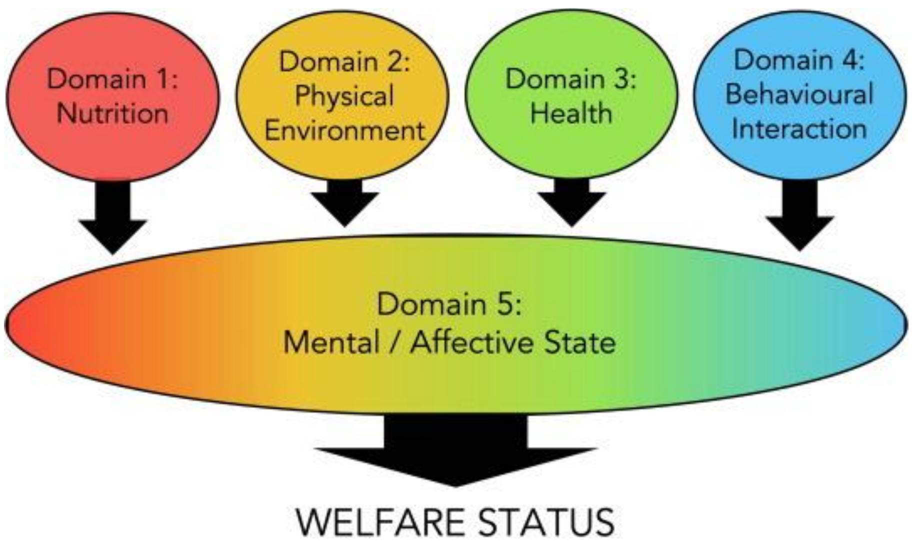

Figure 1.1. The Five Domains Model (Published by Kells, 2022; Adapted from Mellor and Reid, 1994)

The early version of this model focused solely on assessing welfare compromise because the major focus on animal welfare at that time was optimizing biological function to prevent negative outcomes. Furthermore, the range of negative affective states included in the original model was limited to thirst, hunger, anxiety, fear, pain and distress (Mellor and Reid 1994). As time has passed, the Five Domains model has been updated to reflect current animal welfare science thinking by stating that preventing suffering is not sufficient for ensuring animal welfare. Animals must also have opportunities to experience positive emotions (Mellor, 2015; Grandin, 2022).

1.1.1.1. Nutrition (Domain 1)

Domain 1 focuses on the provision of water and food to individual animals. Adequate nutrition and the availability of food and water are physiological requirements for ensuring an animal's welfare. Animals whose water and food intake are restricted experience hunger and thirst as well as weakness due to starvation. This can be reversed by providing enough food for the animals as well as adequate clean water (Mellor et al., 2020). Additionally, providing animals a variety of foods with different tastes and textures may lead to improvements associated with affective state that are conceptualized in Domain 5 of the model. These include pleasurable experiences associated with consumption. Additionally, different tastes and textures may prevent eating related boredom and disorders associated with invariant diets (Mellor, 2017). For example, increasing novelty of creep feed through flavor diversity stimulated piglet exploratory behavior and feed intake during lactation (Adeleye et al., 2014). Exploratory behavior is known to be an indicator of positive welfare, and in this case, likely to increase solid feed intake and consequently increased weight gain after weaning (Adeleye et al., 2014).

1.1.1.2. Physical Environment (Domain 2)

Domain 2 focuses on the impacts of physical and environmental conditions to which animals are directly exposed (Mellor et al., 2020). Circumstances categorized as unavoidable physical conditions, such as odors, close confinement, thermal constraints, noise, and light-related factors can be associated with negative affect within Domain 5. For example, pigs on partially slatted floors under high temperatures experience thermal stress causing them to release urine and feces on the full floor with the purpose of heat loss (Nannoni et al., 2020). This is indicative of poor welfare since under normal conditions, pigs tend to avoid contact with excreta (Huynh et al., 2005; Nannoni et al., 2020). Enhancing environmental factors that fall within Domain 2 could restore positive affect within Domain 5 by improving physical comfort, olfaction, thermal comfort, and relaxation (Mellor et al., 2020). Heat stress experienced during high environmental temperatures could be improved by floor cooling. A study that investigated the use of electronic cooling pads in heat stressed sows concluded that they improved thermoregulatory measures, and improved litter growth and weaning weight (Johnson et al., 2022).

1.1.1.3. Health (Domain 3)

Conditions associated with Domain 3, such as disease, injury, and lameness (due to disease or husbandry and equipment deficiencies) lead to negative affective states within Domain 5. These include pain, distress, physical weakness and exhaustion, among others (Mellor et al., 2020). Treating any acute and chronic diseases, minimizing any form of injury, and providing sufficient nutrients and practices can good health and functional capacity (Mellor et al., 2020).

1.1.1.4. Behavioral interactions (Domain 4)

Prior to updating the Five Domains Model in 2020, Domain 4 largely focused on animal interactions with the environment and other animals (Mellor, 2017). However, the 2020 version of the Five Domains Model also incorporates animal interactions with humans into Domain 4 (Mellor et al., 2020). This distinction illustrates the different behavioral interactions an animal may engage in and how those interactions may impact an animal’s welfare (Kells, 2022). For example, invariant, barren, and confined environments that are included within Domain 4 give rise to negative affective states within Domain 5, such as boredom, helplessness, and withdrawal.

Play behavior, an indicator of positive welfare in piglets, was observed more in piglets housed in complex or enriched environments (Chaloupkova et al., 2007). Providing animals with environments that are novel, and allow for foraging and exploration opportunities, lead to positive affective states such as playfulness, focused and energized animals (Mellor., et al 2020). A study evaluating space requirements and enrichment reported that pigs with larger spaces enriched with bars, rags and tires performed more exploratory behaviors than pigs housed in smaller spaces with no enrichment (Beattie et al., 2000).

Pigs are social animals that actively interact with each other through social nosing, which consists of pigs touching each other's snout (Camerlink and Turner, 2013). Pigs who have limited interaction with their conspecifics may experience loneliness, depression, or sexual frustration which negatively affects their emotional state within Domain 5. However, when animals are allowed to interact, they develop social bonds and have opportunities to perform natural social behaviors (Lee et al., 2022). These include play behavior, a positive indicator of animal welfare known to increase weight gain, and positively impact feeding and drinking behaviors in weaner pigs (Franchi et al., 2023).

There are also causal relationships between handler attitudes and behavior towards pigs and pigs' fear of humans (Hemsworth and Coleman, 2011). Human interaction is capable of shaping piglets' development and their subsequent responses to various management procedures (Johnson et al., 2022). Piglet interactions with humans begin on their first day during parturition and continue throughout their lifetime. Animals who experience negative interactions with handlers who are insensitive, impatient, and unskilled will often exhibit long flight distances, freezing, anxiety, fear, panic (Mellor et al., 2020). On the other hand, animals who experience positive interactions with their caretakers are more likely to perceive their caretakers positively (Luna et al., 2021).

1.1.1.5. Mental/Affective State (Domain 5)

Affective experiences, or the overall mental state, of the animals are accumulated in Domain 5 as a result of Domains 1-4 (Mellor, 2017). The fifth Domain, which provides an indication of the overall welfare state of the animal, consists of both positive and negative affective states (Mellor, 2017). Each domain within the Five Domains Model can be used to evaluate and improve the welfare of animals in captivity. This thesis focuses on the welfare of swine raised in commercial production systems, particularly within Domains 2, 4, and 5.

1.2. Environmental Complexity to Improve Swine Welfare in Commercial Production Systems

1.2.1. Swine Production in the United States

The swine industry in the United States is largely vertically integrated, with production becoming highly specialized through the use of multi-site production systems. Instead of incorporating multiple stages of production (e.g. farrowing, growing, finishing) at a single site, multi-site systems focus on one stage of production per site before transferring pigs to a new location for the next phase of production (Tokach et al., 2016). Therefore, swine production companies often oversee the gestation and farrowing phases of production within company-owned facilities before contracting with independent producers to carry out the grow-finish phase of production at their independently-owned facilities (Mayda, 1998). With this, there has been a gradual decrease in the total number of U.S. swine farms while the number of animals raised on individual farms has increased (Giamalva, 2014). Increasing farm size has allowed for the introduction of important production methods that have helped increase productivity of the swine herd (Tokach et al., 2016).

There are currently 4 phases of pork production in the United States. These include the breeding and gestation phase, farrowing, the nursery phase, and the grow-finish phase. The breeding and gestation phase include the breeding and housing of mature gilts and sows during the 114-day gestation period. At approximately 107 days of gestation, sows enter the farrowing phase where they are moved to a separate space for farrowing. Sows in the United States are typically housed in individual stalls during this phase to facilitate nursing and reduce the likelihood of piglet crushing once they have farrowed (Nicolaisen et al.,2019). At 18-21 d post-farrowing, the piglets, which are approximately 6-7 kg, are weaned from their sow and moved onto trailers to be transported to a nursery or wean-to-finish facility where they undergo the nursery phase. Meanwhile, the sows are cycled back to the gestation rooms to repeat the breeding and gestation phases.

The nursery stage includes housing newly weaned pigs until they are 8-9 weeks old and weigh approximately 25 kg (Pederson, 2018). This stage allows pigs to transition from liquid to solid feed and develop their immune health (Humphrey et al., 2019). Finally, the grow-finish phase houses pigs as they grow from approximately 28 kg to their 80-120 kg market weight at approximately 5-6 months of age (Pederson, 2018). This phase involves improving feed efficiency through proper nutrition as the pig grows, resulting in better nutrient digestibility, less feed wastage, and increased profitability to the producer (FDA, 2014). In commercial production, the nursery and grow-finish phases are commonly conducted in the same space, with pigs remaining in the same pen throughout both phases. Pigs are then transported to a processing plant for slaughter following the grow-finish phase.

In recent years, animal welfare legislation has established minimum standards for acceptable housing in many countries around the world (FAO, 2014). However, in the United States, industry-wide on-farm welfare changes are largely driven by consumer preferences, food industry initiatives, and state-driven legislation instead of federal legislation (Kendall et al., 2006; Ufer, 2012; Wolf et al., 2016). Regardless, any major changes to animal housing and husbandry procedures for the purpose of improving animal welfare can be costly to the producer due to economically tight production conditions (Pederson, 2018). One-time costs like altering or building new infrastructure and ongoing costs such as training personnel and the purchase of materials required for alternative housing systems or enrichment (Fernandez et al., 2021) often require considerable economic investments.

In commercial production systems, pigs are often kept in barren housing conditions on slatted floors without bedding, enrichment material, or outdoor access (Zander et al., 2013). Slatted floors are preferred due to cleanliness, reduced labor and improved manure management (Lindemann et al., 1985). However, under barren conditions, it is difficult for pigs to express various natural and highly motivated behavioral patterns, including exploration and foraging (Van de Weerd and Day, 2009). Provision of preferred substrates within commercial systems, like straw, is not optimal as they may lead to issues with cleanliness, increased ammonia concentration levels, or issues with manure management (Van der weed et al., 2006). For these reasons, the behavioral welfare of pigs housed in intensive production systems is often viewed as being compromised for the sake of hygiene, which has led to a large volume of research examining the potential use of environmental enrichment for improving their welfare (Van de Weerd and Day, 2009).

1.2.2. Environmental Enrichment

Environmental enrichment is the modification of a captive-environment to improve the biological functioning of animals and enhance animal welfare by allowing them to perform more of their species-specific behaviors (Newberry, 1995). Within the Five Domains Model, environmental enrichment is largely represented within Domains 2 and 4 and can be described as an advantageous change in the environment of captive animals when meeting four general criteria. Specifically, the enrichment should: 1) increase species-species behavior, 2) maintain or improve health, 3) improve the economics of the production system, and 4) be practical to employ (Van de Weerd and Day, 2009; Young, 2013)

There are 5 types of enrichment (Bloomsmith et al., 1991; Young, 2013): 1) Social enrichment, which can be divided into contact with either conspecific or allospecific animals, and in a non-contact form, 2) occupational enrichment, which could incorporate psychological tasks, like a puzzle or physical exercise, 3) physical enrichment that incorporates design or objects (*e.g.* toys) within the enclosures (Martins et al., 2015), 4) sensory enrichment which targets visual, auditory and olfactory senses (*e.g.* images, music, scented objects), and 5) nutritional enrichment, which can incorporate food delivery to the animal (Mercer et al., 2022). Proper environmental enrichment reduces incidence of abnormal behavior and leads to performance of "natural", species-specific behaviors such as foraging, exploration, positive social interaction, and play (Van de Weerd and Day, 2009).

Researchers have also demonstrated an effect of environmental modification on meat quality. Beattie at al. (2000) found that pork from pigs reared in barren environments exhibited greater cooking losses and lower levels of intramuscular fat compared to pork from pigs reared with straw and additional space. Greater amounts of intramuscular fat are associated with improved tenderness and water holding capacity in pork (Candek-Potokar et al., 1998). Furthermore, enriched environments may improve pig growth rate. For example, pigs housed in straw-bedded pens had higher daily weight gain than their counterparts (van de Weerd et al., 2006).

Providing suitable substrates, such as straw and wood shavings, in combination with more space per animal as environmental enrichment improves pig welfare by meeting their behavioral requirements (Bolhuis et al., 2006; Van Dixhoorn et al., 2016). However, implementing these types of enrichment on a commercial farm is challenging compared to a small-scale experimental setting. Common concerns expressed by producers include cost, risk to manure pumps, and additional resources required to ensure enrichment objects are properly cleaned and sterilized to avoid biosecurity risks (Peden et al., 2021). Research on how to promote positive behavioral states via practical and economic enrichment methods in commercial intensive farming systems is still needed.

1.2.3. Early Life Experience and Enrichment as it Relates to Future Welfare States

In addition to the beneficial effects of enrichment on an animal's current welfare state, early life exposure to environmental enrichment may also lead to future improvements in animal welfare. Environmental enrichment has positive effects on the social development of pigs at a later stage. For example, piglets that were comingled during lactation and provided with larger spaces showed increased play behavior on d 14 compared to piglets that were not mixed at all during lactation (Salazar et al., 2018). Additionally, piglets that were socialized with unfamiliar pigs prior to weaning exhibited decreased agonistic behaviors and greater levels of average weight gain during the first 12 hours after mixing in the nursery phase (Ledergerber et al., 2015).

Enrichment in the form of increased environmental complexity early in life provides animals with opportunities to structure and organize their environment, which reduces stress by giving them a sense of control over their surroundings later in life (Van de Weerd et al., 1997: Van de Weerd et al., 2002: Wiepkema and Koolhass, 1993). Previous work with 21 d old rats has shown that providing toys and a running wheel, as well as larger cages results in better spatial learning performance at 3 months of age, compared to rat pups housed in standard cages (Leggio et al., 2005). This effect is thought to be mediated through the hippocampus, as enrichment produces hippocampal alterations like neurogenesis within the dentate gyrus, an area of the hippocampus that is important for memory function (van Praag et al., 1999).

Sow exposure to environmental enrichment during the gestation phase alters the future HPA-axis activity and behavior of her offspring. In a study by Tatemoto et al. (2019), piglets born from sows kept in enriched environments from 90-114 days of gestation exhibited reduced salivary cortisol at 28 (day of weaning) and 35 days of age compared to piglets born from sows in barren gestation environments. The only instance of greater salivary cortisol concentration for the piglets born from enriched sows occurred immediately on the day of weaning (0600 h on day 28). Additionally, piglets born from sows within enriched gestation environments exhibited lower aggressiveness on day 4 after weaning and fewer lesions on day 42 after weaning compared to piglets of sows kept in barren gestation environments (Tatemoto et al., 2019). This implies that the stress experienced by the mother within a barren gestation environment may also alter the development of the amygdala which plays a role in mediating fear, anxiety, aggressiveness and emotional learning (Balleine and Killcross, 2006; Chiba 1996; Tatemoto et al., 2019).

Early exposure to increased environmental complexity may also have beneficial effects on future immune system reactivity in pigs. For example, cognitive enrichment (*i.e.* enrichment that requires an animal to complete a demanding task for a reward) has been reported to increase IgG concentration and *in vitro* T-cell proliferation to con A, while also accelerating wound healing (Ernst et al., 2006). However, the same cognitive enrichment reduced LPS-induced proliferation of B-cells (Ernst et al., 2006).

Pigs with early and regular human contact develop a positive relationship with their caretakers and are less fearful later in life (Rault et al., 2020), implying a positive emotional state (Brajon et al., 2015). Therefore, it is important for pigs to experience positive interactions with their caretakers early in life as they are subjected to many routine husbandry practices that they may perceive negatively, such as vaccinations and surgical castration (Lucas et al., 2023).

Finally, early-life experience may also affect meat quality at slaughter. For example, when slaughtered at 6 months of age, meat from pigs reared with increased farrowing stall space and straw before weaning tended to have greater pH at slaughter than meat obtained from pigs who were reared in barren environments (Chaloupkova et al., 2007).

1.2.4. Early-life Environmental Enrichment for Reducing Stress at Transportation

While several studies have focused on the advantages of early life exposure to environmental enrichment for improving future welfare states, few have specifically focused on the provision of enrichment through increased early-life environmental complexity as it relates to pig welfare during the transportation phase at market weight (Lucas et al., 2023). Pigs in the United States are typically transported at least twice in their lifetime, first as young pigs when they are weaned and transported to grow-finish facilities, and again at market weight when they are transported for slaughter (Volslarova et al., 2017). This is attributed to the multi-site nature of production that is common in North America (Marchant-Forde and Marchant-Forde, 2005).

Transportation involves a multitude of overlapping potential stressors (Schwartzkopf-Genswein et al., 2012; Faucitano and Lambooij, 2019), such as vehicle design, handling at loading and unloading, space conditions, and weather (Lambooij, 2014), as well little or no previous experience ascending and descending a ramp (Novak et al., 2020). For example, loading and unloading pigs for transportation plays an important role in animal welfare and economics of the pork industry, and can be a major stressor for pigs (Garcia and McGlone, 2015). The design of the loading ramp and chute have a significant effect on pig welfare. The goal of the loading ramp or chute design should be able to facilitate easy pig movement and reduce the incidence of slips and falls. Successful pig movement can be achieved by use of the correct angle incline on ramps. Ramp angles of 20° or less are recommended as a general guideline for loading pigs (National Pork Board, 2023). Research has shown that angles over 20 degrees causes increased balking and backing up behaviors in pigs (Phillip et al., 1988), increases the number physical interventions by the handler (Gouman et al., 2013), and increases loading and unloading times (Warris et al., 1991). According to the National Pork Board's Transport Quality Assurance guidelines, proper ramp and chute designs should have cleats spaced 8 inches apart. If the process of transport is stressful for a pig, the ultimate result could be a reduction in meat quality, as well as pigs that are fatigued, injured, or ultimately die due to the stressors experienced (Bench et al., 2008).

An estimated 1% of all market pigs are affected by injuries and other losses related to transport (USDA, 2019). The National Pork Board reported approximately 200,000 truckloads amounting to approximately 35,000,000 pigs that were transported for marketing in 2022

(National Hog Farmer, 2023). This would imply a loss of approximately 350,000 pigs. Stress resulting from the transport process also negatively affects carcass quality that resulting in carcass depreciation due to severe skin lesions and meat quality defects due to abnormal postmortem muscle acidification (Faucitano, 2001, 2010; Schwatzkorpf-Genswein et al., 2012). It is therefore in the interest of all stakeholders to minimize transportation stress.

Pigs can be trained to accept some irregularities in management and hence react less vigorously to novelty (Reid and Mills, 1962). Therefore, increasing environmental complexity within the pigs' home pens at an early age may be a useful method for improving loading and unloading during transportation. Modification of swine housing by adding ramps to pens during the nursery phase may help familiarize pigs with ascending and descending ramps. Previous work has shown that provision of a ramp during the nursery phase increases the loading speed at marketing (Novak et al., 2020). In poultry, a study by Stratmann et al. (2015) found that modification of an aviary by providing ramps and platforms reduced laying hen keel borne damage by 23% and reduced falls and collisions by 45% and 59% respectively. These results imply that access to a simple structure, such as a ramp during the nursery phase, could be used to reduce the novelty associated with loading and unloading at market weight in pigs. Further research on how animals handle these stressors would be valuable to minimize economic losses associated with transport and improve swine welfare.

1.3. Conclusion

In conclusion, ensuring the welfare of commercially raised swine is a complex concept that is determined by several factors including nutrition, physical environment, health, and behavioral interactions, which give rise to an animals affective and overall welfare state. The focus of this thesis is to determine whether early-life exposure to a ramp in the nursery pen affects the behavior of pigs during the nursery phase, as well as during loading and unloading at market weight. Chapter 2 specifically focuses on the effect of adding ramps to a nursery pen on the growth performance and behavior during the nursery period and during loading at market weight. Chapter 3 focuses on whether exposing pigs to a ramp during the nursery phase of production affects loading and unloading behavior at market weight.

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2. THE EFFECTS OF RAMPED NURSERY HOUSING ON PIG BEHAVIOR AND PERFORMANCE DURING THE NURSERY PHASE OF PRODUCTION

2.1. Introduction

Indoor commercial swine production systems are characterized by relatively low labor input, low space allowance and the use of slatted floors with little or no bedding materials (van der Weerd and Day, 2009). These systems have a number of advantages including ease of cleaning and management, and protection against predators (Bammert et al., 1993). However, limited space and absence of rooting materials, which is typical of commercial intensive systems, may lead pigs to develop abnormal and harmful behaviors such as tail biting, ear biting, and aggressiveness (Kittawornrat and Zimmerman, 2011). These behaviors lead to stress and poor performance (Oostindjer et al., 2011). Given the potential for behavioral problems to arise within intensive housing systems, practical environmental enrichment may be useful to improve swine welfare (Van de Weerd and Day, 2009).

Environmental enrichment is the modification of a captive-environment to improve the biological functioning of animals and enhance animal welfare by allowing them to perform more of their species-specific behaviors (Newberry, 1995). Various enrichment materials such as straw, increased space, and cognitive stimulation are used by pigs (van de Weerd and Ison, 2019; Zebunke et al., 2013). However, some substrates (*e.g.* straw) in intensive slatted housing systems present challenges associated with cleanliness and manure management (van de Weerd et al., 2006). Hence, research on providing environmental enrichment has shifted to increasing environmental complexity where housing conditions combine inanimate stimuli such as extra space, novel materials and objects as an alternative to the use of substrate materials in commercial housing systems (Jirkoff, 2015). A specific example includes the modification of pens by adding ramps and platforms that can be used by pigs (Laves et al., 202; Novak et al., 2020).

Modification of pig penning by increasing usable space has shown to be beneficial for pigs by promoting good hygiene (Phillip and Fraser, 1989) and improving the ability of piglets to cope with challenges such as exposure to a novel environment (Lucas et al., 2023). For example, pigs given access to elevated platforms within their pens display fewer stereotypic behaviors (Bulens et al., 2017), reduced aggressive behaviors (Laves et al 2021: Novak et al., 2020), as well as increased or no changes to body weight (Laves et al, 2021; Novak et al., 2020).

This chapter is one portion of a larger study that builds upon previous work by Novak et al. (2020) which assessed the effect of adding ramps to a nursery pen on pig behavior and growth performance during the nursery period and during loading at market weight. The objective of the current study was to determine whether increasing environmental complexity (*i.e.* as a form of enrichment) by providing a ramp in the nursery pen affected the behavior and productivity of pigs during the nursery phase. We hypothesized that a ramp in the nursery pen would have positive effects on their behavior and have little effect on their growth and productivity. Specifically, we predicted that pigs with a ramp in their pen would exhibit reduced aggression, increased active postures, increased feeding and drinking, and no differences in growth performances compared to the pigs without a ramp in their pen.

2.2. Materials and Methods

2.2.1. Animal Care and Use Statement

All experimental procedures were approved by the South Dakota State University (SDSU) Institutional Animal Care and Use Committee (Protocol #2107-041E). The current project was carried out at South Dakota State University's wean-to-finish facility in Brookings, SD, USA from March to August 2022.

2.2.2. Animals and Housing

At approximately 21 d of age (range:17 to 21 d of age), 560 weaned piglets (DNA 610 x PIC genetic lines) were transported by trailer to the SDSU wean-to-finish facility. Upon arrival, pigs were placed in a total of 20 pens (21 m^2) in groups of 26-27 pigs. Each pen had fully slatted concrete floors. One five-space dry feeder (1.8m total length: SD Industries, Alexandria, SD 57311) and two cup waterers were provided in each pen for *ad libitum* feeding and drinking. The facility is equipped with a single M-Series FEEDPro system (Feedlogic by ComDel Innovation, Wahpeton, ND). Diets were formulated according to NRC requirements for the pigs' stages of production (NRC, 2012). Temperatures within the facility were controlled to maintain thermoneutral temperatures within the pens, along with a single heat lamp to provide supplemental heating for each pen for six weeks. Artificial lighting was provided within the facility between 0800 h and 1900 h.

Upon arrival, pigs were assigned to one of two experimental treatments, with the pen serving as the experimental unit: 1) access to a ramp within the pen during the nursery phase (**RAMP; Figure 2.1)**, or 2) a standard pen with no access to a ramp (**CONTROL; Figure 2.1**). Pigs within the RAMP treatment had access to a ramp (1.7m x 0.5m, 20° angle) and resting platform (1.1m x1.6m x, 0.7m) located at the top of the ramp. Both the ramp and platform were constructed with powder coated steel. Railings were placed along the sides of the ramp and platform to prevent animals from falling off. Pigs in the CONTROL treatment were housed in a conventional pen of the same area, but without a ramp. Following the 6-week nursery phase, the ramps were removed from the RAMP pens and all pigs underwent the grow-finish phase in standard penning. Experimental pigs were not moved from their home pens at any point during the experiment, other than to collect pen weights for body weight (BW) estimation on d 0, 10, 21 and 47 of the nursery phases.

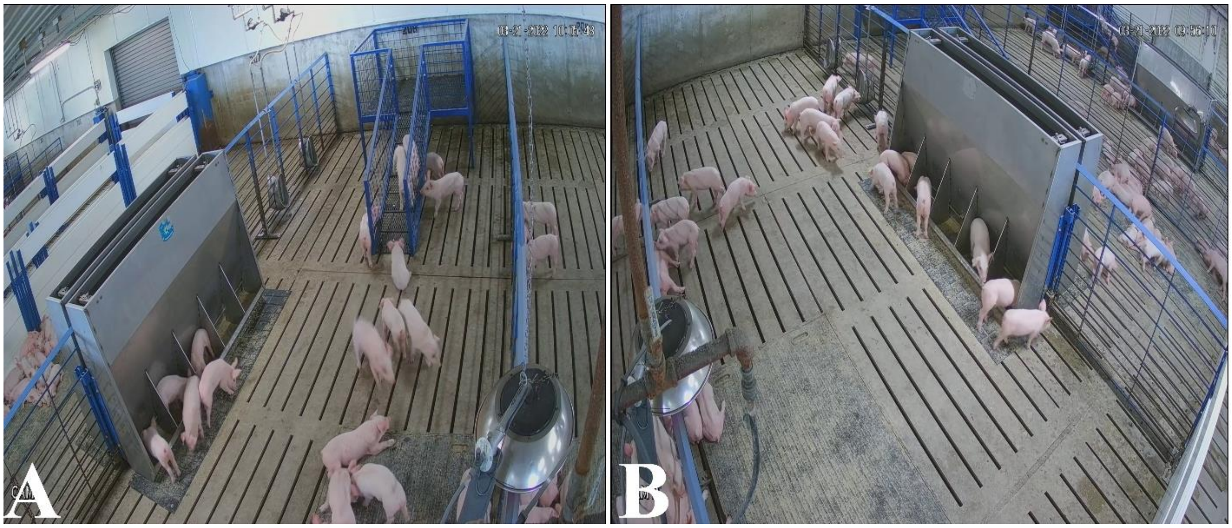

Figure 2.1 RAMP (A) and CONTROL (B) treatment pens. The RAMP pens had a platform which pigs could access via a ramp. The CONTROL pen had no platform and ramp.

2.2.3. Body Weights and Feed Intake

Feed intake (FI) and body weight (BW) were determined on days 0, 10, 21, and 47 for calculation of average daily gain (ADG), average daily feed intake (ADFI) and feed to gain ratio (F:G). To calculate FI, the amount of feed dispensed was collected by the automated feeder that routinely supplied feed with the facility. Then a previously developed equation was used to determine the amount of food remaining in the feeder at each time point (Perez-Palencia et al., 2021). Briefly, a feed density stick was place in the feeder and the amount of empty space (measured in inches) between the feed and the top of the feeder was measured. Using the information, the amount of feed leftover in each feeder was determined as follows:

FL = -15.335 * (X) + 618.26, where FL = leftover in the feeder and X = the measurement of the empty space in the top of the feeders (inches).

Together, these data were used to measure FI on a per pen basis, which was averaged on a per animal basis. Feed intake and BW data were used to determine ADG, ADFI, and F:G.

2.2.4. Behavioral Observations and Ethogram Development

Behavioral observations began one day after introduction of weaned pigs in the nursery. Individual video cameras (Lorex LBV2531U Security Cameras, Lorex Technology Inc., Markham, Canada) were installed above each pen to ensure full coverage of each nursery pen. Recordings were collected continuously for the first 14 days and then one day every week until the end of the nursery period (6 weeks after piglet placement).

Recordings were transmitted and stored on a digital video recorder (Lorex D441A6B-Z DVR, Lorex Technology Inc., Markham, Canada). After video collection, all video recordings were saved to an external hard drive, merged together, and converted to MP4 format (VideoProc, Digiarty Software Inc., hengdu, Sichuan Province, China) for behavioral coding using a commercially available coding software (The Observer XT 15; Noldus Information Technology, Wageningen, Netherlands). Eating, drinking, posture (lying and standing), and fighting were collected using the video recordings from d 1, 2, 3, 6, 19, 26, 33, 39 of the experimental procedure (Table 2.1). On each of those days, observations were conducted for 60 minutes at 0800, 1200, and 1600 h using a 5-minute instantaneous scan sampling method. The scan sampling method was determined using a 6-hour portion of the collected data, where a 5-min scan sampling recording rule resulted in similar results when compared with a continuous sampling recording rule. This allowed us to determine the percentage of pigs within the pen performing each behavior at each interval timepoint. All behavioral data were coded by a single observer (MLK).

Table 2.1. Ethogram used for behavioral data collection during the nursery period.

Behavior	**Definition**
Feeding	Piglet stands with its head in the feeder.
Drinking	Piglet stands with its mouth or snout touching the drinking nozzle.
Fighting	Forceful interactions using head or body between ≥ 2 piglets, with or without biting.
Standing	Piglet is upright on all four legs, stationary or moving.
Lying	Piglet is resting on its belly or side, with head raised or lowered, asleep or awake.

2.2.5. Statistical Analysis

Data were analyzed using the GLIMMIX procedure in SAS (v. 9.4; SAS Institute, INC. Carry NC). Treatment (RAMP vs CONTROL), hour (0800 h, 1200 h, 1600 h), experimental day (1, 2, 3, 6, 19, 26, 33, 39) and all two- and three-way interactions were included as fixed effects. Pen was a random effect. To account for multiple measurements on one pen, hour nested within date was fit as a random effect, with pen as a subject. Different covariance structures were tested and the covariance structure that converged in SAS with the lowest Akaike Information Criterion value was chosen. Differences between treatments were estimated using DIFF option in LSMEANS statement. Repeated measures comparisons between treatments were adjusted using Tukey's method. A *P*-value of less than 0.05 was used as the threshold for significance.

2.3. Results

2.3.1. Nursery Performance Data

Mean BW, ADG, ADFI and F:G ratio of the RAMP pigs did not differ from that of the CONTROL pigs (Table 2.2). No interactions were detected, hence no differences occurred on individual days.

Table 2.2. Performance data (LS Means ± SE) during the nursery period between the RAMP and CONTROL pigs. No differences were observed in BW, ADG, ADFI and F:G ratio between the treatment groups

Measure	**CONTROL**	**RAMP**	***P*-value**
BW (kg)	12.65 ± 0.21	12.88 ± 0.21	0.3
ADG (kg)	0.35 ± 0.01	0.035 ± 0.01	0.9
ADFI (kg)	0.55 ± 0.01	0.55 ± 0.01	0.9
F:G	1.65 ± 0.07	1.58 ± 0.07	0.4

2.3.2. Nursery Behavior

No behavioral differences were observed between RAMP and CONTROL pigs throughout the observation period (**Table 2.3**). An hour effect was observed for eating behavior ($P = 0.01$; **Figure 2.2**), where a lower percentage of pigs eating were observed at 1200 h compared to 0800 h and 1600h.

Table 2.3. Percentage of pen behavior performance (LS means ± SE) during the nursery period organized by experimental treatment. Pigs in the RAMP treatment were given access to a ramp and platform in their pen during the nursery period. Pigs in the CONTROL treatment were not given access to a ramp and platform.

Behavior	**CONTROL**	**RAMP**	***P* - *value***
Eating	2.30 ± 0.13	2.20 ± 0.13	0.4
Drinking	0.48 ± 0.06	0.53 ± 0.07	0.5
Standing	5.52 ± 0.22	5.38 ± 0.22	0.6
Lying	8.64 ± 0.82	7.74 ± 0.82	0.3
Fighting	0.79 ± 0.12	0.79 ± 0.12	0.9

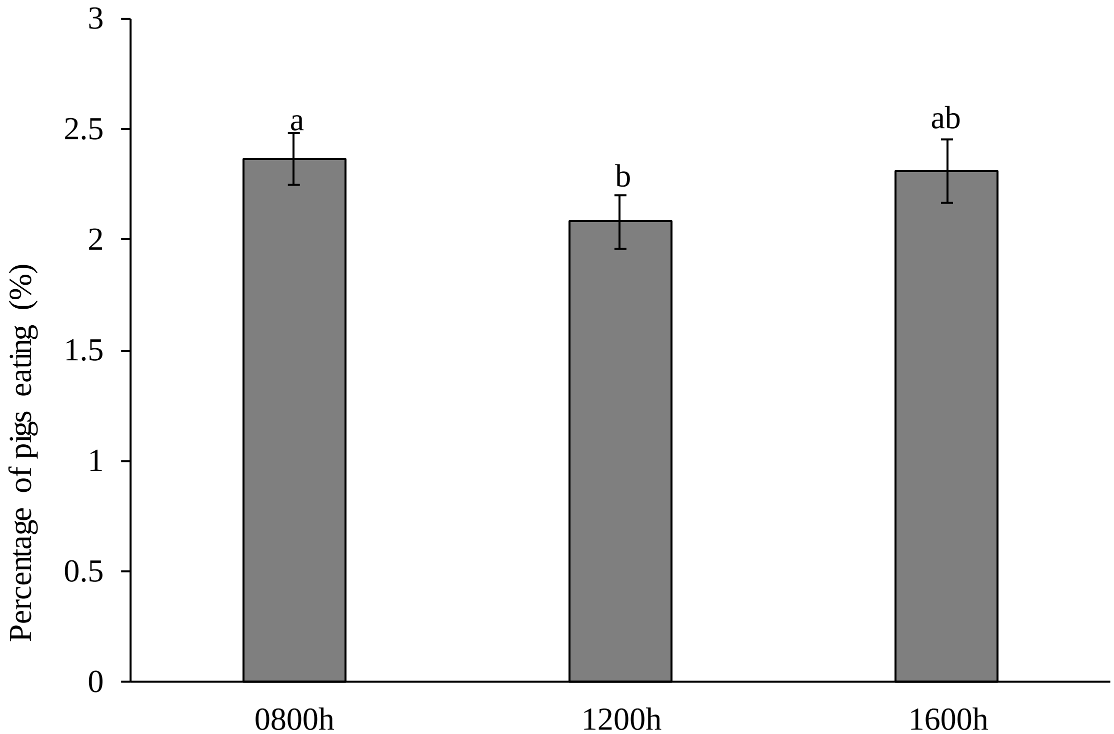

Figure 2.2. Percentage of pigs performing eating behavior LS Means ± SE at 0800 h, 1200 h and 1600 h. Different superscripts indicate significant differences (P < 0.05).

A day effect was also observed for eating behavior, where the percentage of pigs observed eating was lower on d 1 compared to d 3, 6, 19, 26, 33, and 39 ($P < 0.0001$; **Figure 2.3**). The percentage of pigs observed eating was lower on d 2 compared to d 6, 19, 26, 33, and 39. Finally, the percentage of pigs observed eating was greater on d 19 compared to d 39. A day effect was observed for drinking behavior ($P < 0.001$; **Figure 2.4**). However, after adjusting for multiple comparisons, no differences for drinking behavior were observed. Additionally, hour by day interactions were observed for standing ($P < 0.001$; **Figure 2.5**), lying ($P < 0.001$, Figure 2.6) fighting ($P < 0.001$; **Figure 2.7**).

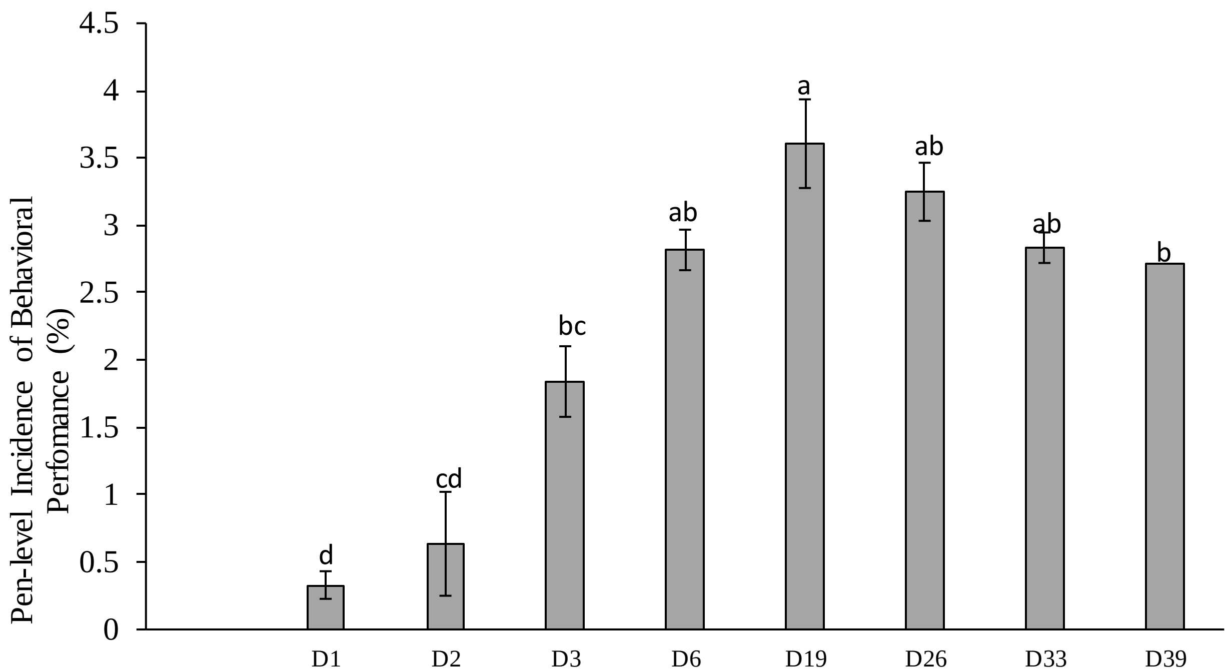

Figure 2.3. Incidence of eating behavior (LS means ± SE) organized by experimental days 1, 2, 3, 6, 19, 33 and 39. Different superscripts indicate differences among the experimental days ($P < 0.05$)

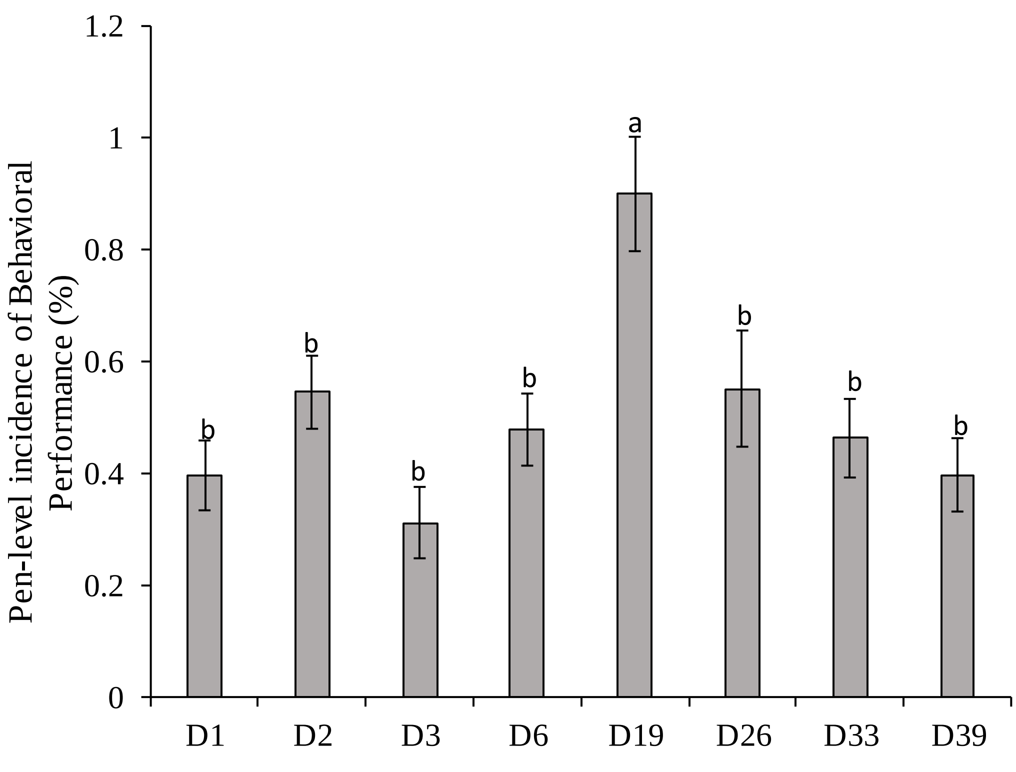

Figure 2.4. Incidence of drinking behavior (LS mean ± SE) organized by experimental days 1,2,3,6,19,33,39. Different superscripts indicate differences among experimental day- ($P < 0.05$).

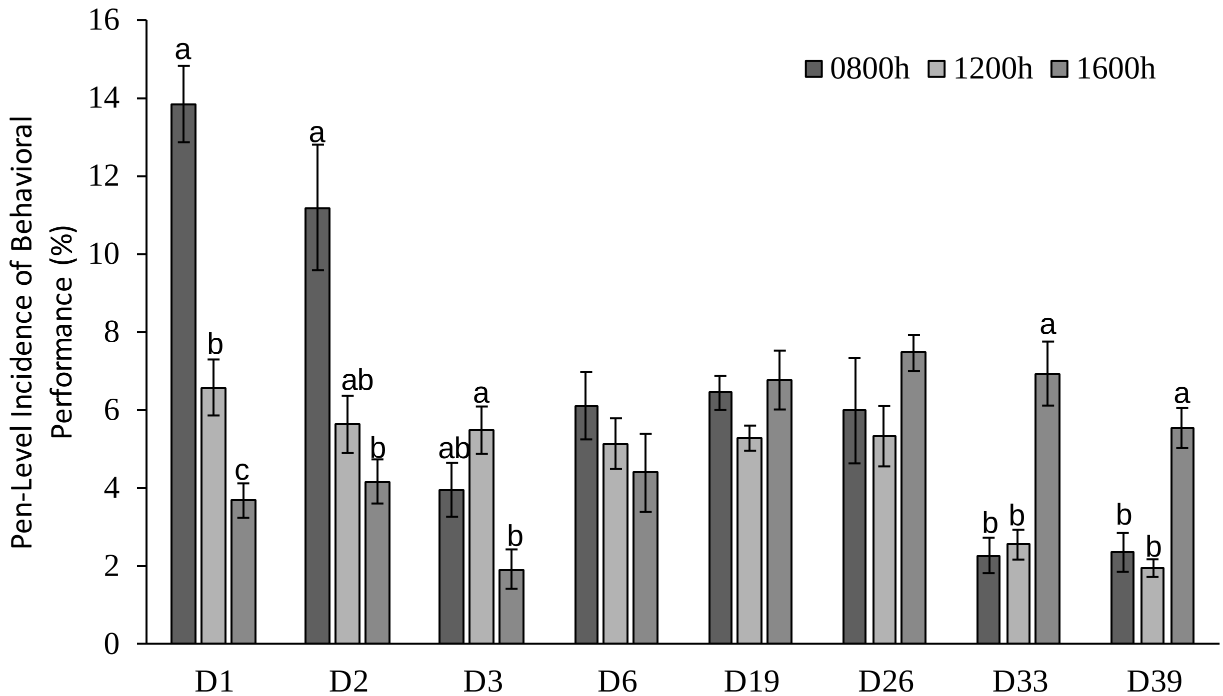

Figure 2.5. Day by Hour interaction for standing behavior during the nursery phase at 0800, 1200, and 1600 h. Different superscripts indicate significant differneces within day (P < 0.05).

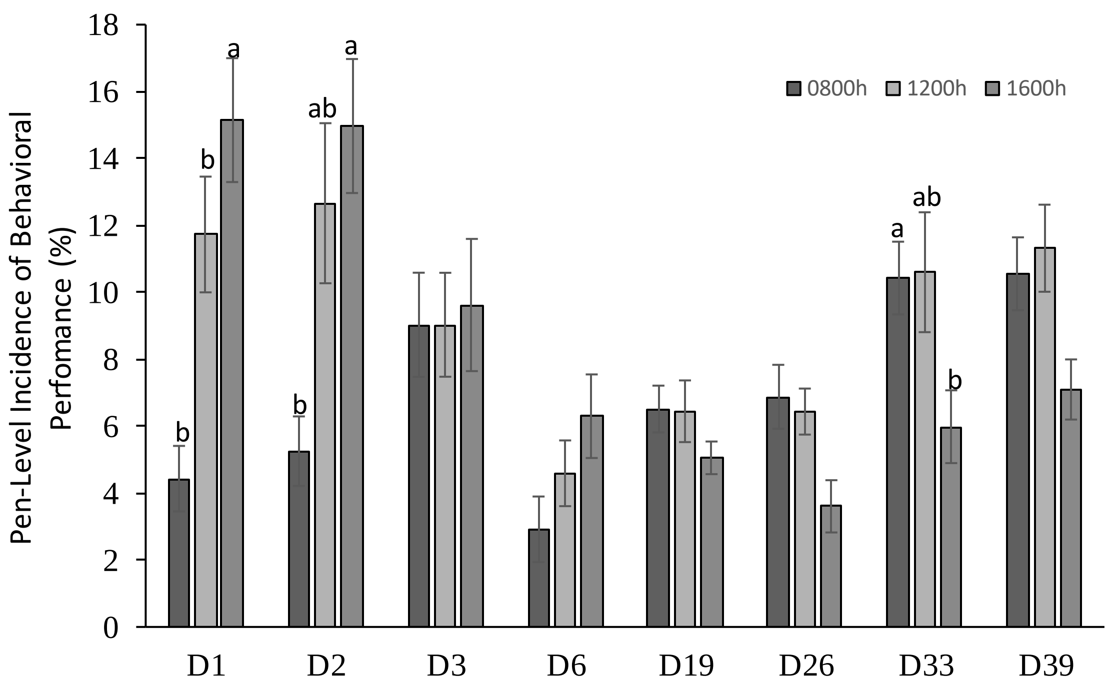

Figure 2.6. Day by Hour interactions for lying behavior during the nursery phase at 0800, 1200 and 1600 h. Different superscripts indicate significant difference within day (P < 0.05).

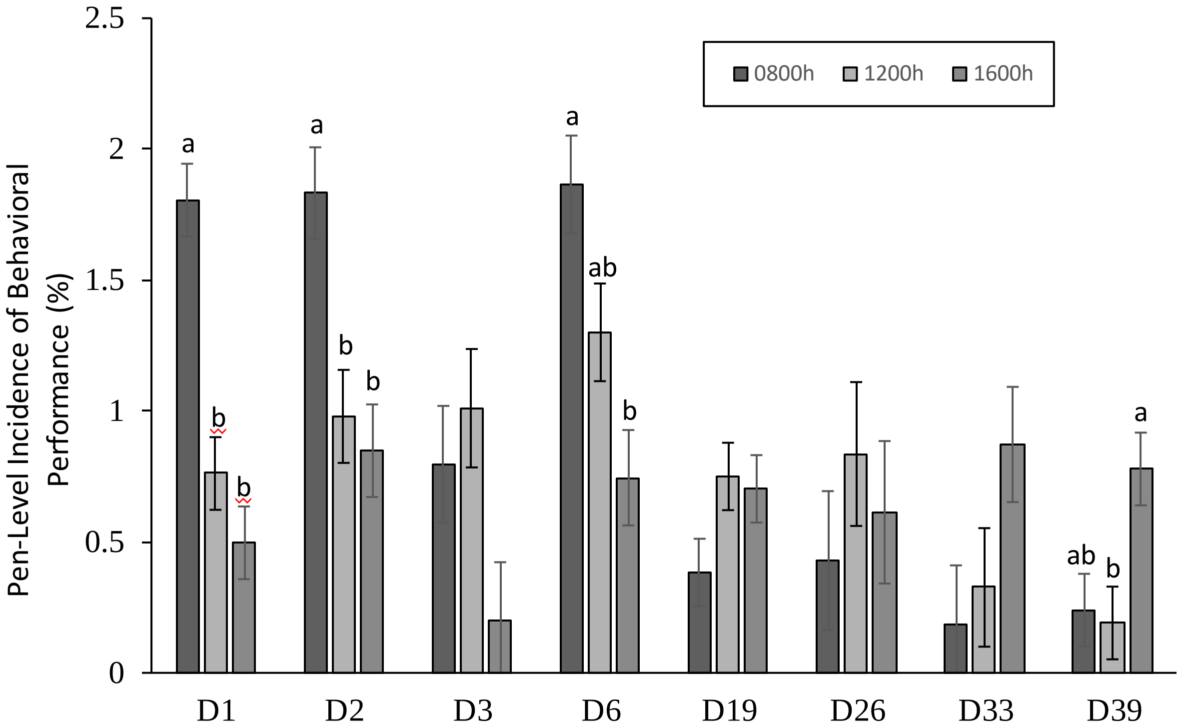

Figure 2.7. Day by Hour interactions for fighting behavior during the nursery phase at 0800, 1200 and 1600 h. Different superscripts indicate significant differences within day ($P < 0.05$).

2.4. Discussion

Studies on the use of ramps and platforms in pig pens date back to the late 1980s (Phillips et al., 1988; Philips and Fraser 1987 & 1989). These studies focused on economical usage of barn space (Phillips and Fraser, 1986). Most recently, studies evaluating the use of ramps in pig housing have focused on whether they affect behavior (Novak et al., 2020: Fels et al., 2018), growth performance (Novak et al., 2020; Laves et al., 2021) as well as loading speed at market weight (Novak et al., 2020).

In commercial intensive systems, lack of space can negatively affect swine welfare (Cox and Cooper, 2001). With the need to design housing systems that satisfy the behavioral needs of pigs, offering extra space beyond the recommended requirements could be a method for improving animal welfare. Increased floor space, however, would require a reduction in stocking density or construction of large pens. Both options would likely result in reduced revenue for the farmer (Kausselman et al., 2023). A possible way to increase space without reducing the number of pigs could be to build elevated platforms in already existing pens that can be accessed by ramps.

The objective of this study was to determine whether increasing environmental complexity by adding a ramp and platform would affect the behavior and performance of pigs during the nursery period. Overall, no differences were observed in mean BW between the two treatments in our study. These results correspond to a study by Phillip and Fraser (1986), and Novak et al. (2020) who similarly found no differences in mean BW between the two treatments. Interestingly, in Novak et al (2020), even though ramp provision resulted in no changes to BW, pigs in the ramp treatment exhibited reduced feed intake compared to those without a ramp in their pen. Additionally, some studies showed that pigs with access to ramps in their pens had increased weight gain compared to those that did not (Laves et al., 2021). While we did not observe reduced feed intake or greater body weights in RAMP pigs in the current study, our results align with previous studies that report no negative effects of ramp provision on growth performance.

In our study, eating behaviors were not affected by treatment. This result contrasts with those reported by Novak et al. (2020), where pigs exposed to a ramp exhibited fewer eating behaviors during the nursery phase compared to those that did not have access to a ramp. This difference may be due to differences in feeder location between the two studies. In our study, the feeders were located on the floor, whereas in the study by Novak et al. (2020), the feeders were located on top of the ramp, which pigs had to climb in order to access feed. As a result, pigs in Novak et al. (2020) may have been less inclined to climb the ramp to gain access to feed. The percentage of pigs observed eating was lower at 1200 h compared to 0800 h. This is likely due to piglets that are more active early in the day.

The observed reduction in eating on d 1 and 2 is likely attributed to the pigs transitioning from milk to solid feed following weaning (Brooks and Tsourgiannis, 2003). Pigs require a period of learning to transition from a single milk-based diet to solid feed and water after weaning (Brooks and Tsourgiannis,2003). Pigs are known to later recover from the reduced eating once they get used to solid feed (Wensley et al., 2021). For this reason, water intake is elevated on the first several days post weaning (Brooks et al., 1984). In our study, drinking behaviors were observed to be high on day 19 and no differences in drinking behaviors for the rest of the days.

Although there were no observed differences in posture between the two treatments, the percentage of pigs performing standing behavior was greater at 0800 h on d 1 and 2 compared to 1200 h and 1600 h on d 1 and 2. Similarly, more standing behavior occurred at 0800 h on d 6 compared to 1600 h on d 6. This result could also be attributed to the novel nursery environment following weaning.

The percentage of pigs observed fighting was not altered in response to treatment. Previous studies evaluating the effect of ramps on aggressiveness showed reduced aggression among pigs that had ramps in the pens (Bulens et al., 2017; Novak et al., 2020; Laves et al 2021). Although there were no treatment differences, fighting behavior for all pigs was observed to be greater in the morning hours on d 1, 2, and 6. This could be explained by the fact that pigs were unfamiliar with each other, and were in a completely new environment. Unfamiliar pigs are known to fight more at weaning when mixed together as a way to establish dominance since their normal process of hierarchy formation has been disrupted by weaning (Peden et al., 2018). This could also be due to pigs being very active in the mornings which led to more fights compared to the rest of the hours during the day.

2.5. Conclusion

The objective of this chapter was to investigate whether increasing environmental complexity by adding a ramp and platform to the nursery pen would affect nursery pig behavior and productivity. Our data indicate that adding a ramp and platform in nursery housing has no effect on nursery pig growth performance or behavior. Future work in this area should focus on evaluating the effect of ramp provision on behavioral ramp use and activity to better understand how nursery pigs utilize the pen within the ramp. Additionally, physiological measures should be incorporated to determine whether ramp provision has an effect on the stress response in nursery pigs.

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3. THE EFFECT OF NURSERY PHASE RAMP EXPOSURE ON LOADING AND UNLOADING BEHAVIOR OF PIGS AT MARKETING

3.1. Introduction

Transportation is an essential component of modern swine production, since the farrowing, finishing, and processing phases occur at different sites (Johnson et al., 2013). Pigs encounter a number of stressors during the process of transportation. These stressors can result in injured or non-ambulatory pigs, as well as pigs that die during transportation (Johnson et al., 2013).

The aforementioned outcomes are known to affect pig welfare, meat quality and economics (Driessen et al., 2013). An estimated 1% of all market pigs are affected by injuries and other losses related to transport (USDA, 2019). The National Pork Board reported approximately 200,000 truckloads amounting to approximately 35,000,000 pigs that were transported for marketing in 2022 (National Hog Farmer 2023). This would imply a loss of approximately 350,000 pigs in 2022.

The act of transporting is only one aspect of the transportation process that may be perceived as stressful for pigs. For example, loading at the farm facility and unloading at the slaughter facility may lead to poor welfare outcomes due to the physical layout of the farm, including the construction and angle of the loading or unloading ramp (TQA V8, 2022). Additionally, human-animal interactions during the loading and unloading processes may be perceived negatively by the animals, particularly if those interactions incorporate aversive loading conditions or tools (*e.g.* electric prod use) (Brandt and Aaslying, 2015; Correa et al., 2010).

Given these stressors and the potential for poor welfare outcomes, there is a need to identify methods that reduce stress experienced by market pigs during the transportation process. One potential method for reducing stress caused by loading and unloading during the transport process is to modify the housing system by adding ramps to the pig housing which familiarizes them with ascending and descending the ramps. Animals exposed to increased environmental complexity and stimuli during early life may be better equipped to cope with future challenges encountered in their daily lives (Crofton et al., 2015). While, the effects of early-life exposure to increased environmental complexity on the welfare of market pigs are largely unknown (Lucas et al., 2023), some preliminary work has reported that the addition of ramps to nursery pig housing increases speed of loading at marketing and has no negative effects on pig growth (Novak et al., 2020).

The current study builds upon the preliminary work conducted by Novak et al. (2020). The objective of this study was to determine whether exposing pigs to a ramp during the nursery phase of production (approximately 3 - 9 weeks of age) would affect loading and unloading at the time of marketing (approximately 5 - 6 months of age). We hypothesized that ease of loading and unloading would be improved in pigs that were exposed to a ramp during the nursery phase. Specifically, we predicted that pigs exposed to a ramp during the nursery phase would take less time to ascend and descend the ramp during loading and unloading at market weight. Additionally, we predicted that pigs exposed to a ramp in the nursery phase would exhibit less turnarounds, refusals, slips and falls during the loading and unloading processes.

3.2. Materials and Methods

3.2.1. Animal Care and Use Statement

All experimental procedures involving animals were approved by the South Dakota State University (SDSU) Institutional Animal Care and Use Committee (Protocol #2107-041E).

3.2.2. Animals and Housing

The current project was carried out at South Dakota State University's wean-to-finish facility from March to August 2022. At approximately 21 d of age (range:17 to 21 d of age), 560 weaned piglets (DNA 610 x PIC genetic lines) were transported by trailer to the SDSU wean-to-finish facility. Upon arrival, pigs were placed in a total of 20 pens ($21m^2$) in groups of 26-27 pigs. Each pen had fully slatted concrete floors. One five space dry feeder (1.8m total length: SD Industries, Alexandria, SD, USA) and two cup waterers were provided in each pen for *ad libitum* feeding and drinking. The facility is equipped with a single M-Series FEEDPro system (Feedlogic by ComDel Innovation, Wahpeton, ND) for feeding which was also used to monitor feed dispensed to each pen. Diets were formulated according to NRC requirements for the pigs' stages of production (NRC, 2012). Temperatures within the facility were controlled to maintain thermoneutral temperatures within the pens, along with a single heat lamp to provide supplemental heating for each pen for six weeks. Artificial lighting was provided within the facility between 0800 h and 1900 h.

Pigs were assigned to one of two experimental treatments: 1) access to a ramp within the pen during the nursery phase (**RAMP**; Fig. 1), or 2) a standard pen with no access to a ramp (**CONTROL**; Fig. 1). Pigs within the RAMP treatment had access to a ramp (0.7 x 0.5 m, 20° angle) and resting platform (1.1 x 1.6 x 0.7 m) located at the top of the ramp. Both the ramp and platform were made of powder coated steel. Railings were placed along the ramp and platform to prevent animals from falling off. Pigs in the CONTROL treatment were housed in a conventional pen of the same area, but without a ramp. Following the 6-week nursery phase, the ramps were removed from the RAMP pens and all pigs underwent the grow-finish phase in standard penning. Periodic weigh periods using a pen scale did occur throughout each production phase. However, experimental pigs remained within their originally assigned pens throughout the entire experiment.

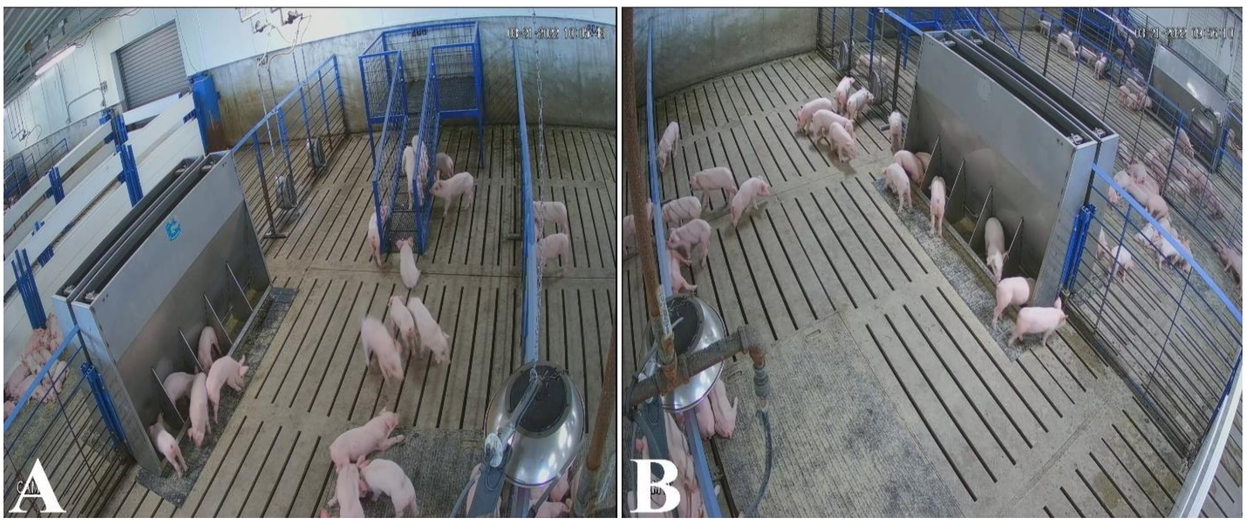

Figure 3.1 RAMP (A) and CONTROL (B) treatment pens. The RAMP pens had a platform which pigs could access via a ramp. The CONTROL pen had no platform and ramp.

3.2.3. Production Performance

Feed intake and BW were determined on days 0.10,21, 47,70,105, and 135 for calculation of average daily gain (ADG), average daily feed intake (ADFI) and Feed to gain ratio (F: G) on a per animal basis. A density stick was used to estimate feed in feeders by volume based on the previously determine equation:

FL = -15.335 * (X) + 618.26, where FL = leftover in the feeder and X = the measurement of the empty space in the top of the feeder (inches).

3.2.4. Loading and Unloading Behavior

The loading process took place on seven different days over a four-week period during August 2022. During each loading day, pigs were moved in groups of four pigs (20 total groups each loading day; 1 group of four pigs from each pen) using a red sort board and loaded onto a standard pot-belly semi-truck trailer by the same experimental personnel (M.L.K). the heaviest animals in each pen were sorted and loaded first. Second personnel followed the experimental personnel to help record data as well as apply an electric prod if required. Each group was required to ascend a covered load-out ramp (6.06 m long;0.9 m wide, 11.1° incline angle). The ramp was constructed out of wood and had cleats which were 0.2 m apart. Two cameras (GoPro Hero 10, GoPro Inc., Santa Mateo, California, USA) were mounted on the ceiling of the load out ramp to collect the total time taken by each group to navigate the load-out ramp. Additionally, the number of trips, turn arounds performed by the pigs on the ramp were recorded.

Data collection began when the front limbs of the first pig in the group stepped onto the ramp and ended when the hind limbs of the last pig in the group stepped onto the trailer. If the experimental personnel were not able to move individual pigs within the group up the ramp during the initial 60 second period of loading, an electric prod was applied to the animal(s) according to approved Transport Quality Assurance (TQA) guidelines (National Pork Board, 2023). After the last pig in each group stepped onto the trailer, the driver of the truck moved the group of 4 pigs into 1 of 4 upper-level trailer compartments and the lower level compartment closest to the cab of the semi-truck, where they remained throughout the remainder of the transport process. Each compartment was large enough to hold 14-19 experimental pigs. Experimental treatments were mixed within the compartments.

Videos collected during the loading phase were transferred from the GoPro cameras and stored on to external hard drives, merged together and converted to MP4 format (VidoeProc, Digiatry software Inc., Hengdu Sichuan Province China). The videos were then coded using the Observer XT15 (Noldus Information Technology, Wageningen, Netherlands).

After the loading procedure, all experimental pigs were then transported for approximately 170 miles from the SDSU wean-to-finish facility near Brookings, South Dakota USA, to Wholestone Farms Inc., the processing facility, in Fremont, Nebraska USA. Upon arrival to the processing facility, pigs were unloaded in mixed treatment groups (minimum group size = 1; maximum group size = 15) by facility employees according to company guidelines. Two handlers (both employees of the processing facility) unloaded the pigs using a rattle paddle and red sort boards. No electric prod was used during the unloading portion of the study. Non-experimental pigs located in two compartments (1 upper-level closest to the trailer ramp required for descending the upper level, 1 lower-level closest to the rear of the trailer) were unloaded first to facilitate data collection on the experimental pigs.

The trailer height was the same as the height of the unloading floor within the facility, so no ramp was required for pigs to exit the trailer leading into the facility. However, since the experimental pigs were housed in 4 upper-compartments within the trailer and 1 lower level compartment that required those pigs to ascend a ramp to the upper trailer level and then descend the ramp to the facility, the total time taken by each pig to descend the ramp (1.68 m long x 1.0 m wide, 20.8º incline angle) within the trailer from their transport compartment to the lower level of the trailer was quantified. Two cameras (Go Pro Hero 10; Go Pro Inc., San Mateo, CA USA) were mounted by experimental personnel for behavioral observation. One camera was mounted within the trailer, at the top of the ramp, while the other camera was mounted within the processing facility where the pigs walked off the trailer. Together, the two cameras allowed experimental personnel to calculate unloading time and the number of trips and turns attempts by individual pigs as they were unloaded. Additionally, data regarding the number of individual pigs who descended the ramp backwards, the number of times a rattle paddle was used by a handler to encourage movement, and the number of pigs' dead on arrival (DOA) were collected. Data were collected from the recorded videos by a single experimental personnel (CJB).

3.2.5. Statistical Analysis

Performance traits were analyzed using MIXED procedure in SAS (v. 9.4; SAS Institute, Inc., Cary, NC). Treatment, diet, and day, along with the two- and three-way interactions were fit as fixed effects. Block was fit as a random effect. A repeated measures statement was used with pen as the subject. Different covariance structures were tested for the repeated statement and the best fit based on AICC was chosen. The LSMEANS statement was used to calculate the treatment by day values and the PDIFF option was used to determine differences between values.

Loading time was analyzed using the MIXED procedure in SAS (v. 9.4; SAS Institute, Inc., Cary, NC). Treatment, day, and their interaction were fit as fixed effects. A repeated measures statement was used with pen as the subject. Different covariance structures were tested and the best fit based on AICC was chosen. The LSMEANS statement was used to calculate the treatment, day, and treatment by day values. The PDIFF option was used to test for differences between values. The FREQ procedure in SAS was used to evaluate differences in frequencies between treatments for the use of the livestock prod and for trips. The chi square option was used to test for significance. Use of livestock prod and trips were analyzed separately for the entire experimental period and by experimental day (1-6).

Trailer unloading times were analyzed using the MIXED procedure in SAS (v. 9.4; SAS Institute, Inc., Cary, NC). Fixed effects included in the model were treatment, day, the use of the rattle paddle (yes or no), compartment within the trailer, and whether or not the pig was backwards (descending the ramp only). Group size was fit as a covariate. Group nested within day was fit as a random effect as was pig order nested within group and day. The LSMEANS statement was used to estimate the treatment values, with the PDIFF option being used to calculate differences between treatments. The FREQ procedure in SAS (v. 9.4; SAS Institute, Inc., Cary, NC) was used to evaluate differences in frequencies between treatments for the use of paddle, pigs going backwards down the ramp, number of turns on the ramp, turn back to front on the ramp, topples and DOAs. The chi square option was used to test for significance. For all analyses, a P-value of less than 0.05 was used as the threshold for significance.

3.3. Results

3.3.1. Production Performance

Mean BW, ADG, ADFI, F: G did not differ between the CONTROL and RAMP pigs (Table 3.1) over the entire growth period.

Table 3.1. Performance data (LS Means ± SE) between the CONTROL and RAMP pigs over the entire growth period. No differences were observed in Mean body weight (BW), average daily gain (ADG), average daily feed intake (ADFI) and feed to gain ratio (F: G) between the two treatments.

Measure	CONTROL	RAMP	P-value
BW (kg)	42.59 ± 0.38	42.76 ± 0.38	0.7
ADG (kg)	0.67 ± 0.007	0.66 ± 0.38	0.7
ADFI (kg)	1.36 ± 0.02	1.32 ± 0.02	0.1
F: G	1.92 ± 0.04	1.84 ± 0.04	0.1

3.3.2. Loading Behavior

An effect of ramp exposure on loading time was observed. Specifically, RAMP pigs required less time to ascend the ramp compared to CONTROL pigs, ($P = 0.002$; Figure 3.2). There was an effect of loading day on loading time ($P = 0.004$; Figure 3.3). Loading time for all pigs on experimental day 1 was greater when compared with experimental days 3, 4 5 and 6. Additionally, loading time was greater on experimental day 2 compared to experimental day 6.

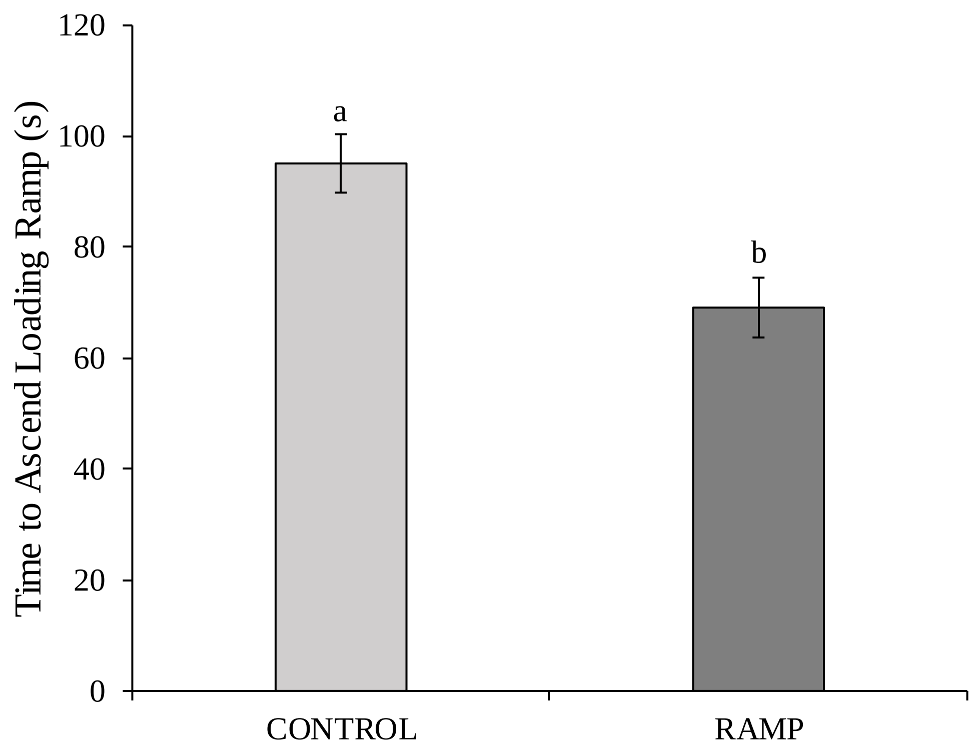

Figure 3.2. Time taken for market-weight pigs to ascend a loading ramp to a standard pot-belly livestock trailer to be transported for market. Pigs in the RAMP treatment were exposed to a small ramp within their enclosure during the nursery phase of production while CONTROL pigs were raised in a conventional pen without a ramp during the same period. Different superscripts indicate significant differences ($P < 0.05$) between treatments.

The livestock prod was used more frequently with CONTROL pigs compared to the RAMP pigs (33 vs 20; $P = 0.02$).

Finally, no differences in trips were observed between the two treatments, 8 vs 4 instances between the CONTROL and RAMP respectively ($P = 0.17$).

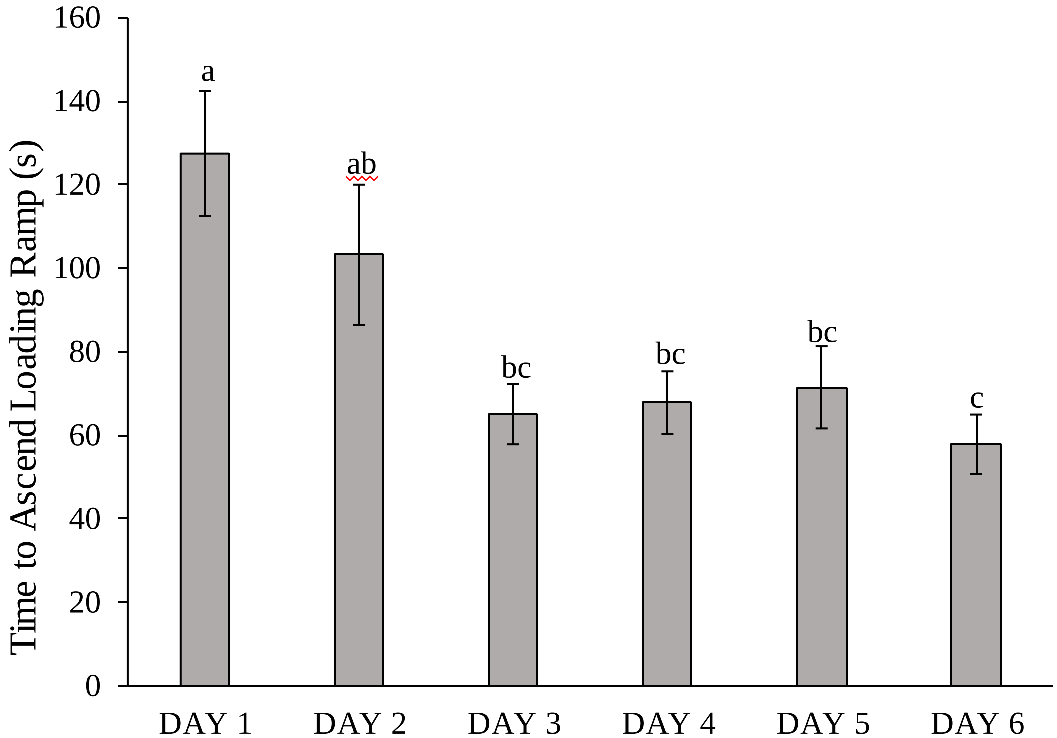

Figure 3.3. Time taken for all experimental market-weight pigs to ascend a loading ramp to be transported for market organized by experimental day (1-6). Different superscripts indicate significant differences (*P* < 0.05) between treatments.

3.3.3. Unloading Behavior

Treatment differences were observed in the time taken to descend the ramp located within the trailer upon arrival to the processing facility (*P* = 0.03; Figure 4). Specifically, CONTROL pigs took less time to descend the ramp compared to the RAMP pigs (Figure 3.4).

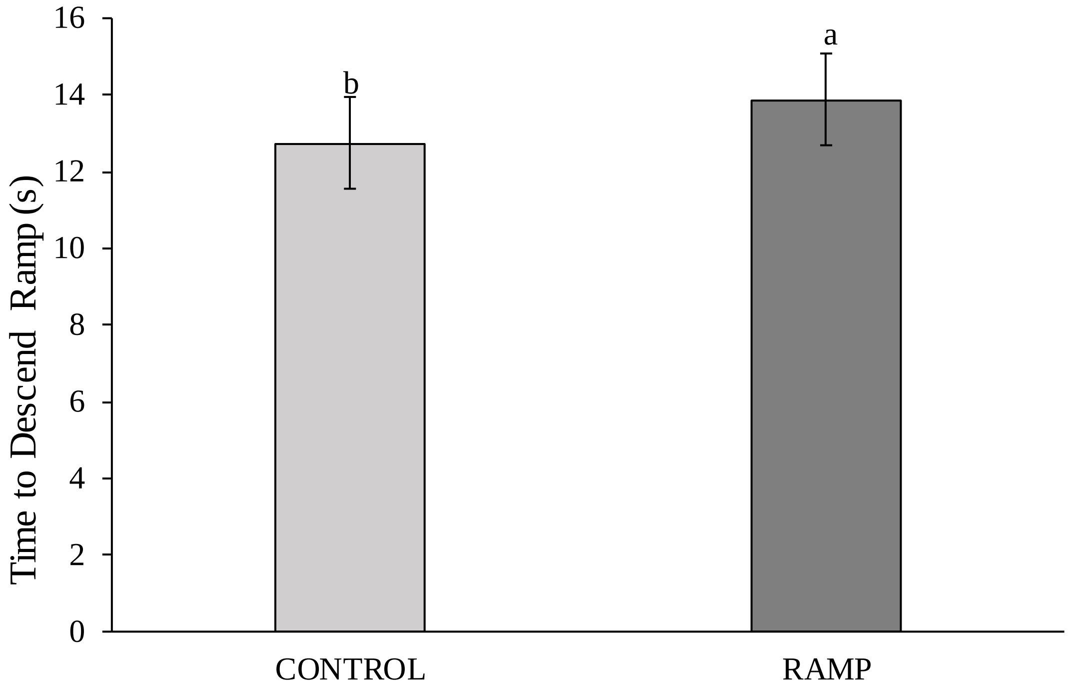

Figure 3.4. Time taken for market-weight pigs to descend a ramp located within a standard pot-belly livestock trailer before entering into the processing facility. Pigs in the RAMP treatment were exposed to a small ramp within their enclosure during the nursery phase of production while CONTROL pigs were raised in a conventional pen without a ramp during the same period. Different superscripts indicate significant differences ($P < 0.05$) between treatments.

There were no differences in turns, rattle paddle usage or DOAs between treatment groups during unloading. Pigs in the RAMP treatment exhibited a greater frequency of descending the ramp backwards compared to CONTROL pigs (Table 3.2). No differences in the number of trips observed between the two treatments. However, greater number of trips were observed on day 5 for the control pigs compared to the rest of the days. ($P = 0.04$).

Table 3.2. Counts of unloading behavioral performance, rattle paddle use, and dead on arrivals (DOA) after arrival to the processing facility. Data are organized by treatment, where RAMP pigs were previously exposed to a ramp and platform during the nursery phase. Pigs in the CONTROL group did not have access to a ramp and platform during the nursery phase.

Behavior	**CONTROL (n = 235)**	**RAMP (n = 238)**	***P* – value**
Turns	2	3	0.5
Trips	5	4	0.7
Paddle Usage	59	61	0.9
Backward movement	2	12	0.02
DOA	2	3	0.5

3.4. Discussion

The ability of an animal to cope with various environmental and husbandry stressors is significant with regards to animal welfare and productivity, given the effect of perceived stress on growth, immune function and reproduction (Moberg, 2000). Early environmental modification has been found to have a number of advantages on the growth (Laves et al., 2021), behavior (Luo et al., 2020) and fear responses (Rault et al., 2020) of pigs later on in their lives. Therefore, increasing environmental complexity early in life may also benefit pigs when exposed to stressors encountered during the transportation process at marketing.

The objective of this study was to determine the effect of ramped nursery housing on the ease of loading and unloading at the time of marketing. Loading and unloading pigs during transportation plays an important role in animal welfare and economics of the pork industry, and can be a major stressor for pigs (Garcia and McGlone, 2015). Ramp angles of 20° or less and chute designs spaced 8 inches apart are recommended by Transport Quality Assurance Guidelines (National Pork Board, 2023) for successful pig movement to be achieved. Its is also recommended to move animals in smaller groups of 3-5 so as facilitate easy movement for the pigs and the handler (TQA V8, 2022).

Overall, no differences in BW were observed between the RAMP and CONTROL pigs over the entire growth period. Our results agree with those reported by Bulens et al. (2017) and Novak et al. (2020) who also observed no differences in growth, a sign that ramp provision during the nursery period has no detrimental effect on the growth of pigs. Alternatively, a study by Laves et al. (2021) found pigs that were kept in a pen with a ramp and platform gained more weight compared to pigs in a standard pen. This attributed to the platforms adding providing additional space for the pigs which they used to escape avoid each other, therefore reducing environmental and social stress, thus positively affecting daily weight gain in nursery pigs.

Pigs that were exposed to a ramp in their pens during the nursery period took less time to ascend the ramp leading to the truck compared to pigs without a ramp in their pen during the nursery period. Our results are similar to those reported by Novak et al. (2020), where pigs given access to a ramp in their pen during the nursery period ascended the ramp faster than those without a ramp in their pen. However, our study differs from Novak et al. (2020) as we did not include a feeder at the top of the ramp, but still observed an effect on loading speed. This result indicates that ramps are readily accepted by weaned pigs within the pen (Fels et al., 2018) and have a beneficial effect on loading speed, because ramps are readily acceptable by weaned pigs (Fels et al.,2018) regardless of feeder location.

A separate study reported that pigs exposed to ramps were faster to load and had a reduced heart rate when moved in a handling course (Lewis et al., 2008).

Grandin (1997) stated that exposure of animals to novel experiences enables them to acclimate to their surroundings, where the ability to regularly interact with novelty decreases fear. In this case, having prolonged access to a ramp during the nursery phase provided an opportunity for pigs to interact and acclimate to the ramp. As a result, this previous exposure likely played a role in the decreased time spent ascending the loading ramp at market weight.

In addition to loading speed differences, between treatments, we also observed differences in loading speed on the different days of loading. Specifically, the time required to ascend the loading ramp on day one was longer compared to days 3,4, 5 and 6. Day 02 was longer than day 6. Days 1 and 2 were not different from one another. While this result is not clear, it could be due to handler experience with the loading process as the experiment progressed.

An electric livestock prod was used more frequently with the CONTROL pigs compared to the RAMP pigs during the loading procedure. A higher frequency of electric prod usage in CONTROL pigs could be attributed to their refusal to ascend the ramp as they were not familiar with it. Electric Prod usage is associated with more falls, fewer stops, less turning around, longer vocalizations, and elevated heart rate, which are known to result into greater blood lactase concentrations at exsanguination, high ultimate pH values, and greater incidence of blood splashed hams (Correa et al., 2010). Future work on this topic should evaluate the effect of ramp exposure on meat quality at market weight.

To the best of our knowledge, this is the first study to evaluate the effects of a ramp in nursery housing on unloading speed and behavior at the processing plant. Pigs are exposed to an unfamiliar environment and handlers during unloading, which can cause stress and negatively affect their welfare and pork quality (Brandt and Aaslyng, 2015). Pigs in the CONTROL group descended the ramp faster than the pigs in the RAMP group. This could be due to the unfamiliarity of the environment encountered by the pigs which made them stressed hence rushed down the ramp. The unloading ramp was 20.8º, quite greater that the recommended 15°, could have been a source of stress leading them to rush down the ramp (Cobanovic et al., 2021). Interestingly, pigs in the RAMP treatment descended the ramp backwards more frequently compared to the CONTROL pigs. This may be due to increased experience with ascending and descending ramps. The ability to descend a ramp backwards could be beneficial for reducing ramp-related injuries as they descend the ramp.

3.5. Conclusion

The present study showed that increasing environmental complexity by adding a ramp in the nursery pen improved pig loading speed at marketing. Additionally, provision of the ramps during the nursery phase had no detrimental effects on pig performance throughout the entire experimental period. A ramp may be an adaptation with potential to improve animal welfare during loading and unloading during the transport process. Future research should aim to look at the effect of a ramp in the nursery on the carcass quality during slaughter. Studies should also look into the use of different materials which are less expensive to build ramps if they would have the same effect on the loading and unloading speed.

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