A PILOT STUDY ON THE PRODUCTIVITY AND BEHAVIOR OF THE GESTATING SOW HOUSED IN A FLEX STALL

BY

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THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Animal Sciences
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2011

Urbana, Illinois

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Abstract

Animal welfare is a controversial topic in modern animal agriculture, partly because it generates interest from both the scientific community and the general public. The housing of gestating sows, particularly individual housing, is one of the most critical concerns in farm animal welfare. We hypothesize that the physical size of the standard gestation stall may limit movement and evoke demands and challenges on the sow to affect the physiological and psychological well-being of the individually housed sow. Thus, improvements in the design of the individual gestation stall system that allow more freedom to move, such as increasing stall width or designing a stall that could accommodate the changing size of the pregnant sow, may improve sow welfare. The objective of this pilot study was to evaluate the effects of a width adjustable stall (FLEX) on productivity and behavior of dry sows. The experiment consisted of 3 replications (block 1, n=4 sows; block 2, n=4 sows; block 3, n=8 sows), and multi-parious sows were allotted to either a FLEX stall or standard gestation stall for 1 gestation period. Sow mid-girth (top of the back to bottom of the udder) was measured 5-6 times throughout gestation to determine the best time points for FLEX stall width expansions. FLEX stall width was adjusted according to mid-girth measurements, and expanded to achieve an additional 2 cm of space between the bottom of the sow's udder and floor of the stall so that sows could lie in full lateral recumbency without touching the sides of the stall. Productivity data recorded included: sow body weight (BW) and BW gain, number of piglets born and born alive, proportions of piglets stillborn, mummified, lost between birth and weaning, and weaned, and litter and mean piglet birth BW, weaning BW, and average BW gain from birth-to-weaning. Lesions were recorded on d 21 and d 111 of gestation. Sub-pilot behavior data were observed and registered for replicate 1 sows using continuous video-records for the l2 hour lights on period (period 1, 0600-1000;

period 2, 1000-1400; period 3, 1400-1800) prior FLEX stall adjustment and 12 hour lights on period post adjustment on d 21, 22, 23, 43, 44, 45, 93, 94, 95. A randomized complete block design with a 2 × 2 factorial arrangement for treatments was used to analyze sow productivity and performance traits. Data were analyzed using the Mixed Models procedure of SAS. A preliminary analysis of data means and numerical trends was used to analyze sow behavior measurements. Sows housed in a FLEX stall had more ($P < 0.05$) total born and a tendency for more piglets born alive ($P = 0.06$) than sows housed in a standard stall. Sow body weight also tended to be higher ($P = 0.06$) for sows housed in a FLEX stall compared to sows housed in a standard stall. There were numerical trends for mean durations of sit, lay, lay (OUT), and eat behaviors to be greater for sows housed in a FLEX stall compared with sows housed in a standard stall. The mean duration of lay (IN) behavior tended to be numerically less for sows housed in a FLEX stall compared with sows housed in a standard stall. There were numerical trends for the mean durations of stand and drink behaviors to be greater for sows housed in a standard stall compared with sows housed in a FLEX stall. The mean frequencies of postural changes and mean durations of oral-nasal-facial and sham-chew behaviors were numerically similar between types of gestation stall. Mean durations and numerical trends indicate that time of day influenced all of the behaviors assessed in this study. The results of this pilot study indicate that the adjustable FLEX stall may affect sow productivity and behavior differently than the standard gestation stall, and thus potentially improve sow well-being. Future research should continue to compare the new FLEX stall design to current housing systems in use and examine physiological traits and immune status in addition to behavioral and productivity traits to assess the effects that this housing system has on the overall welfare of the gestating sow.

Acknowledgements

Upon my admittance to the University of Illinois, Department of Animal Sciences, my arrangements as a graduate student were somewhat unusual. Dr. Jennifer Sobie whom I had worked with during my undergraduate studies at Western Michigan University had moved to the Urbana-Champaign area and become an adjunct professor in the Animal Sciences department. With the help of Dr. Janeen Salak-Johnson and Dr. Amy Fischer, she made it possible for me to pursue a graduate career in animal behavior. My advising situation was complicated, but I was fortunate to receive valuable guidance. One year into my studies, Dr. Jennifer Sobie had to unexpectedly move back to Michigan. Dr. Janeen Salak-Johnson was kind enough to take me under her wing and help me pursue a research project in behavior. Without her mentoring and support, this project would not have been possible. I'd like to thank Dr. Janeen Salak-Johnson for introducing me to the way behavior relates to stress and animal welfare which, in turn, has led to my greater understanding of animal behavior. I'd also like to thank Dr. Robert V. Knox and Dr. Matthew B. Wheeler for being a part of my committee and taking the time to review my thesis, offer suggestions, and answer my questions. A special thanks to Marcial Guevara and Ashley DeDecker for their support and help, and patiently answering my endless questions during my time at the U of I. My thanks also to Dr. Amy Fischer, Dr. William F. Simmons, and Dr. A. Lane Rayburn for letting me assist them in teaching their courses.

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Chapter 1: Introduction

Animal welfare is a controversial topic in modern animal agriculture, partly because it generates interest from both the scientific community and the general public. This has led to a discrepancy of opinions regarding animal care and management practices. The housing of gestating sows, particularly individual housing, is one of the most critical concerns in farm animal welfare. Although animal scientists, veterinarians, and policy makers agree that decisions regarding farm animal well-being should be based on sound science, concern among animal protection organizations has caused a debate over whether the general public's values and ethics should be taken into consideration when evaluating farm animal welfare. A survey by Lusk and Norwood (2008) found that a slight majority (56.4%) of respondents believed that decisions regarding farm animal welfare should be made by experts rather than being based on public opinion. Moreover, fifty-four percent of the respondents believed that decisions regarding animal welfare, such as sow housing, should be based on scientific measures of animal well-being, rather than moral and ethical views. Thus, the solution appears simple: base decisions and the implementation of laws regarding farm animal well-being on scientific research and recommendations.

However, the root of the problem lies in the fact that those individuals who believe that animal welfare decisions should be made by the public, consider animal welfare to be higher on a list of societal problems compared to those that believe that animal welfare decisions should be made by experts (Lusk & Norwood, 2008). This makes it unlikely that decisions regarding farm animal welfare will ever be based exclusively on scientific data.

How the gestating sow ought to be accommodated in commercial pork production is one of the most important issues facing the swine industry as a whole. Individual housing methods, in which sows are kept in a 2- x 7-foot gestation stall (or crate) are being continually criticized by non-governmental special interest groups for their available space, and thus freedom of movement. Consequently, the general public has formed widespread opinions on this issue, and decisions and laws regarding sow housing have been based largely on public opinion rather than scientific measures of animal well-being. Following European trends, the gestation crate has now been banned in seven states through either voter ballots or legislative initiatives (Springsteen, 2009). As a result, a variety of alternative housing systems have been suggested and tried, but most research studies indicate that these systems do not necessarily improve sow well-being (McGlone et al., 2004b; Rhodes et al., 2005). In fact, numerous studies have concluded that sow welfare is equivalent in either individual or group housing systems (Barnett et al., 2001; CAST, 2009; McGlone et al., 2004b). Because there are both positive and negative aspects associated in all systems currently used, it is difficult to objectively and scientifically rank housing systems for overall welfare (Barnett et al., 2001; Gonyou, 2007; Levis, 2007; McGlone et al., 2004b; Rhodes et al., 2005; Salak-Johnson et al., 2007; Stalder et al., 2007).

Despite negative public opinion regarding the individual gestation stall, it is crucial that we continue to scientifically address the effects that this production environment has on the welfare of the gestating sow. The gestating sow changes in body size as parity and stage of gestation progress (McGlone et al., 2004a). Research indicates that sow body depth increases an average of .12 cm per day from day 23 to day 115 of gestation (McGlone et al., 2004a). This means that a sow is approximately 12.7 cm deeper, from back to udder, at the end of pregnancy. Moreover, the physical size of the sow varies within groups of sows from the same location, as well as between sows from different farms (McGlone et al., 2004a).

The physical dimensions of the commercial gestation stall are long and tall enough to accommodate the majority of sows; however stall width may limit movement. A limitation of movement may evoke demands and challenges on the sow that could potentially affect their physiological and psychological well-being. In the overall assessment of sow welfare, perhaps more attention needs to be directed toward the design of the housing system rather than the housing system *per se.*

Thus, improvements in the design of the individual gestation stall system that allow more freedom to move, such as increasing stall width or designing a stall that could accommodate the changing size of the pregnant sow, may improve sow welfare. Therefore, the objective of this thesis was to evaluate the effects of an adjustable stall on productivity and behavior of the individually housed sow.

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Chapter 2: Literature Review

Overview

The welfare of farm animals is a major public issue worldwide. Scientifically sound assessments of farm animal well-being are crucial to the sustainability of US agriculture. One of the most critical welfare concerns facing the swine industry today is how the gestating sow ought to be accommodated in commercial pork production (Bracke et al., 2002a,b; CAST, 2009; Gonyou, 2005; McGlone et al., 2004b). Individual housing methods, in which sows are kept in a 2- x 7-foot gestation stall (or crate) are being continually criticized by several animal protection organizations, thus drawing considerable attention from the general public. As a result, many decisions regarding the sow housing issue have been founded on widespread opinions based on media reports, and perhaps emotions, rather than scientific data. Lawmakers are continually under pressure by the government, industries, and consumers to introduce proposed legislation for increased animal welfare. Arizona, California, Florida, and Michigan have banned sow stalls through voter ballots, while Colorado, Maine, and Oregon have banned stalls through legislative initiatives (Springteen, 2009). Moreover, selected European countries and the European Union have banned or are phasing out the use of gestating stalls by 2013 (CAST, 2009). As negative public beliefs increase, it is crucial that researchers continue to develop scientifically sound approaches to study and better understand animal care and management practices to ensure that animal well-being in this specific area is not being compromised.

Unfortunately, there is still a considerable lack of available scientific data to support and defend sow housing issues. It is essential that we develop a scientific approach to validate and implement alternative housing systems and management strategies that are both practical and economically viable, but will also effectively improve sow well-being. Many scientific evaluations indicate that sow welfare is similar whether sows are kept in individual stalls or group pens (Barnett et al., 2001; CAST, 2009; McGlone et al., 2004b). Although studies concerning alternative housing systems have assessed stress physiology, behavior, performance, and production, no one system has been clearly identified as being better than another for sow welfare (Barnett et al., 2001; Gonyou, 2007; Levis, 2007; McGlone et al., 2004b; Rhodes et al., 2005; Salak-Johnson et al., 2007; Stalder et al., 2007). In fact, there are both positive and negative aspects associated in all systems currently used. Thus, the advantages of current housing systems need to be retained, while additional research identifies existing problems and opportunities for improvements.

How Does Stress Affect Welfare?

Animal welfare must be defined by certain measureable characteristics of an animal that are universally accepted throughout academia, industry, and government. However, it is not uncommon for individuals to integrate moral views with biological facts, which inevitably leads to different interpretations and disagreements when it comes to assessing animal welfare. Within the research community, there are three broad approaches used by scientists in studying animal welfare: the ‘nature of the species,’ the ‘feelings-based,’ and the ‘functioning-based’ approaches (Duncan & Fraser, 1997). While some scientists prefer the ‘nature of the species’[1] or ‘feelings-based’[2] approach, the ‘functioning-based’ or ‘homeostasis’ approach is the most universally accepted because it defines animal welfare in terms of biological fitness, that is, the animal’s abilities to successfully survive, grow, and reproduce. One definition of animal welfare that

[1] The ‘nature of the species’ approach puts emphasis on keeping animals under natural conditions, allowing them to perform their full repertoire of behaviors (Fraser, 2008).
[2] The ‘feelings-based’ approach emphasizes the affective states of animals and the reduction of negative subjective feelings, such as suffering or pain (Fraser, 2008).

supports this approach is "the welfare of an individual is its state as regards its attempts to cope with its environment" (Broom, 1986). This definition refers to both how much has to be done in order to cope with the environment, as well as the extent to which those coping attempts were a success.

Coping mechanisms are a key part of the basic concept of stress and are activated in response to real or perceived challenges or threats. When an animal has insufficient resources resulting in an unsuccessful response, the animal fails to maintain or re-establish bodily integrity and psychic stability, and thus fails to adapt or cope. The degree of an animal's success in achieving adaptability is determined by the nature of the stimulus, genetic adaptability, adaptation status, and relationship between stimulus and response. When an animal perceives a stimulus in the environment as threatening, biological response(s) are evoked in response to that specific stimulus that has the potential to overwhelm the capacity or ability for the animal to cope. A behavioral response is always activated first because it is the least costly for the animal. Many a times, an animal may find coping difficult, but may succeed after a simple behavioral change is implemented, thus mitigating longer-term adverse consequences. Other attempts to cope include functioning of body repair systems, immunological defenses, and emergency physiological responses. A failure to cope or difficulty in coping corresponds to poor welfare (Broom, 1991). It is here that we see the connection between stress and welfare.

One common way to define stress is: events that are found to be threatening to an individual and elicit physiological and behavioral responses. Thus, stress implies exposure to unpleasant conditions and is manifested through adverse effects. However, determining what exactly qualifies as unpleasant and what is adverse is debatable. Therefore, the definition of stress is defined differently among many scientists. Broom and Johnson (1993) defined stress as “an environmental effect on an individual which overtaxes its control systems and reduces its fitness or appears likely to do so.” Moberg (1980) defined stress as “a complex multidimensional phenomenon promoted by several noxious or unpredictable stimuli that causes a physiological response aimed to maintain or to recover the body homeostasis.” More recently, Curtis (2009) defined stress “resulting from an animal’s failure to adapt to challenging environmental conditions – reduces an animal’s fitness. Unless mitigated, stress inevitably will lead to harm and even the untimely death of that animal.” Although these definitions vary slightly, they all encompass one central concept: when an animal is exposed to a stressor, and thus has reduced fitness, that animal will activate a behavioral or physiological response to try to cope with the situation. Moreover, if the animal is able to readily adapt, exposure to the stressor actually causes no harm.

Behavior as a Measure of Welfare

The publication of *Animal Machines* (Harrison, 1964) played a pivotal role in the beginning of the modern welfare movement. Although Harrison hardly discussed animal behavior in her book, her main implication that animals are viewed as machines, raised public concern regarding the welfare of farm animals. As a result, the British Government appointed a technical committee composed of two veterinarians, four agriculturalists, a surgeon, and two zoologists to inquire into the welfare of animals kept under intensive livestock husbandry systems (Gonyou, 1994). The committee derived its name, Brambell Committee, from its chairman, F.W.R. Brambell. The Brambell report, published in 1965, distilled what it called the “Five Freedoms” into a single sentence: “An animal should at least have sufficient freedom of movement to be able without difficulty, to turn around, groom itself, get up, lie down and stretch its limbs." The report acknowledged the study of animal behavior as a critical aspect in the assessment of animal welfare.

While the Brambell report became quite popular for its discussion concerning freedom of movement, many agriculturalists were of the view that other aspects concerning animal welfare were often overlooked or insufficiently addressed. In 1979, the British government appointed a standing advisory committee on animal welfare, known as The Farm Animal Welfare Committee (FAWC). In an attempt to perhaps correct an imbalance of suggestions in the original Brambell report, the FAWC published the "New Five Freedoms." The recently revised (FWAC, 2009) freedoms are listed as follows:

1. Freedom from Hunger and Thirst - by ready access to fresh water and a diet to maintain full health and vigor.
2. Freedom from Discomfort - by providing an appropriate environment including shelter and a comfortable resting area.
3. Freedom from Pain, Injury or Disease - by prevention or rapid diagnosis and treatment.
4. Freedom to Express Normal Behavior - by providing sufficient space, proper facilities and company of the animal's own kind.
5. Freedom from Fear and Distress - by ensuring conditions and treatment which avoid mental suffering.

Freedoms 1-3 have generally been accepted and addressed by agriculturalists, while the latter two reflect current societal concerns (Stookey, 1992). The Five Freedoms have also been divided into production traits (1-3) and ethological issues (4-5) (Webster, 1993). Thus, ethology and behavior as a measure of welfare also are crucial in assessing animal welfare.

Although the “Five Freedoms” are not formally recognized by any authoritative body in the USA, the United States Department of Agriculture (USDA) has regulations regarding animals used in research and for exhibition using similar “freedoms” (McGlone, 2003). The USDA requires that animals used in research and for exhibition must be able to turn about freely; to stand, sit, or lie in a comfortable, normal position; and to walk in a normal manner (USDA, 2002). These rules, based on general, non-scientific beliefs or opinions and not scientific data, became part of the USDA Animal Welfare Act (1966). Today, there is much public concern about how much space an animal needs before its welfare is compromised. Adequate space requirements for the gestating sow are of particular concern. The body of scientific research comparing differing sow housing systems is steadily increasing, and often uses behavioral observations, amongst other measures (productivity, immune status, stress physiology) to assess overall sow welfare.

As mentioned earlier, when an animal is experiencing difficulty in coping with a challenge or threat, a behavioral response is always activated first. In fact, some consider measurement of behavior as the best indicator of long-term stress (Broom & Johnson, 1993). The FAWC’s fourth freedom states that animals should have the freedom to express normal behavior. Consequently, abnormal or deleterious displays of behavior are generally accepted as indicators of poor welfare (Gonyou, 1994). Abnormal behavior is defined as: behavior that differs in pattern, frequency, or context from that which is shown by most members of a species in conditions that allow a full range of behavior (Broom & Fraser, 2007). In some cases, an animal may engage in abnormal behavior in an attempt to cope with its environment (Broom & Fraser, 2007). Nonetheless, that animal’s welfare may be poorer than that of an animal not expressing abnormal behaviors. Behavioral assessment does not improve the welfare of animals unless we can determine the underlying cause of the behavior and eliminate it. Many of the behaviors that are considered indicative of poor welfare have multiple causes, making behavioral research a crucial aspect in improving farm animal welfare.

Stereotypic behavior is perhaps the most common abnormal behavior of behavioral inquiry and concern in the assessment of animal welfare. Stereotyped behavior is most commonly defined as "a repeated, relatively invariate sequence of movements which has no obvious purpose" (Broom & Fraser, 2007). Stereotypies are derived from various types of source behavior. Repeated action patterns such as general locomotion and behavior involving the mouth, are often part of an animal's behavioral repertoire. Hence, it is important to distinguish not only whether a behavior is repeated, but whether it has no obvious purpose.

The two most common stereotypic behaviors displayed by the gestating sow are oral-nasal-facial (ONF) and sham-chewing. ONF behavior is when a pig manipulates any inanimate object with its mouth, nose, or facial area. Sham-chewing is typically considered continuous chewing while no feed or substrate is in the mouth (de Leeuw, 2004). When classifying ONF behavior as a stereotypy, one must consider a sow's behavioral repertoire. It is normal for sows to investigate their environment with their head, specifically their face, mouth, and nose (CAST, 2009). Maintenance behaviors, i.e. behaviors that have obvious functions such as eating and drinking, are also classified as ONF patterns (CAST, 2009). Therefore, similar ONF patterns (eating, drinking, rooting) may have differing motivations. When sows are housed in individual stalls, the availability of environmental features, such as the physical design of the stall can influence stereotypic behavior. Sows that are housed in a stall with vertical bars (as opposed to horizontal bars) may develop alternative stereotypies such as sham-chewing because they are unable to bar-bite. In assessing animal welfare, the significance of the development of alternative stereotypical behaviors in terms of motivation is unclear (CAST, 2009).

In some situations, stereotypic behavior may actually be helping an animal cope with its environment. For example, sows housed in stalls performed more stereotypies than those housed by the use of girth tethers, yet the former had larger litters (McGlone et al., 1994). von Borell and Hurnik (1990) found a positive correlation between frequency of stereotypic behavior (for sows housed in stalls) and litter size. However, sows that did not perform stereotypies, had larger litters than those that did. Thus, evidence that stereotypies may help sows cope with aversive environments is not yet clear and can be contradictory. In other situations, a stereotypic behavior may have helped an animal cope with its environment in the past but is no longer doing so, or may actually have no obvious function and instead be a behavioral pathology. It is normal for animals to experience physical and psychic stresses during their lifetime, which is why animals are equipped to cope with most stressors. Despite the fact that some stereotypies may help an animal cope with the environment, stereotypies indicate reduced welfare, though some animals may have poorer welfare than others. In the assessment of animal welfare, it is important for scientists to distinguish when animal suffering is present on a continuum that ranges from very well to very ill.

Issues and Concerns Regarding the Standard Gestation Stall

Although 60-70% of sows in the U.S. are housed in individual gestation stalls, public opinions and misconceptions concerning this specific housing system have the potential to have a major impact on swine production (Barnett et al., 2001). Florida, Arizona, Oregon, Colorado, California, Maine, and Michigan have banned or will ban gestation stalls in the upcoming years (Springsteen, 2009). Unfortunately, much of the general public that has voted against the gestation stall have based their decisions on emotions rather than the scientific literature available on this topic.

Indoor sow housing systems were developed during the mid-twentieth century to avoid extreme weather conditions, predators, and parasitic and enteric diseases (CAST, 2009). Farmers then sought to find ways to maximize building efficiency while still avoiding the former conditions. This led to the creation of the standard gestation stall in the early 1960s, and by 1990, individual gestation stalls were the most common sow housing system used in the United States (CAST, 2009).

The standard gestation stall has several benefits compared to traditional group housing systems. Firstly, indoor housed sows are protected from environmental conditions such as heat, cold, precipitation, etc. (Deen et al., 2005). Secondly, potential aggression is eliminated because mixing of sows is prevented, whereas sows housed in group pens are generally regrouped with unfamiliar pigs several times throughout their lifetime (Gonyou, 2005). Consequently, sows will often fight to establish a dominance hierarchy (Gonyou, 2005). Moreover, fighting can result in lameness, skin wounds, infertility, and exhaustion (Deen et al., 2005). A third benefit of the standard gestation stall is that farmers can easily regulate individual feed intake to achieve high productivity and longevity (Gonyou, 2005). Each sow can be fed according to its body condition score and stage of pregnancy. Competition for feed is eliminated, resulting in less bullying and aggression (Gonyou, 2005). Individual stalls also assist in making husbandry more manageable. Farmers are able to more easily supervise sows and control herd health. Signs of morbidity such as decreased feed intake or discharge from the vulva can be more easily detected and monitored (Estienne & Harper, 2003).

Despite the many benefits of the standard gestation stall, it is often criticized for its available space. The body size of modern domestic pigs has increased as a result of the rigorous selection process used to improve meat production (Whittemore, 1994). In addition to selection, multiple factors, such as parity, body weight (BW), and stage of gestation have been reported to influence the gestating sow's body size (McGlone, 2004a). Space requirements vary among individuals and the standard gestation stall has not been altered to accommodate sows with larger body dimensions. Therefore, freedom of movement has become one of the most popular concerns among the general public.

The individual gestation stall was designed to accommodate a sow's static space requirements, or the three-dimensional space that accommodates an animal's nominal body dimensions (Brody, 1945; Midwest Plan Service, 1987). The majority of gestation stalls do not accommodate a sow's dynamic space requirements, which includes additional space needed to change postures. Therefore, several studies have examined the physical size of the gestating sow (Baxter & Schwaller, 1983; Curtis et al., 1989; McGlone et al., 2004a).

McGlone et al. (2004a) found that sow body depth increased an average of .12 cm per day from day 23 to day 115 of gestation. This means that a sow is approximately 12.7 cm deeper at the end of pregnancy. The commercial gestation stall has an inside dimension of less than 58 cm and a length of 213 cm. McGlone et al. (2004a) suggested that larger sows housed in stalls less than 57 cm wide might be in an uncomfortable position. Guidelines issued by the National Pork Board (NPB) and food retailers state that sows housed in individual stalls should be able to lie down without parts of their body extending into the neighboring sow's stall (NPB, 2002). Results from McGlone et al. (2004a) indicated that 95 percent of sows would be entirely contained in a stall that was less than 72 cm in width. Curtis et al. (1989) studied static and dynamic space requirements for the gestating sow during late gestation. Their sample of sows had static space requirements 2 to 5 percent higher than the sows studied by McGlone et al. (2004a), supporting the fact that individual sows vary in size. Differences could be due to genetics, feeding level, or farm-to-farm variation (McGlone et al., 2004a).

Anil et al. (2002b) examined how the relationship between stall size and sow size affects postural behavior. Results suggested that sows take more time to complete a postural change when the stall size is less relative to the sow's size. Negative correlations were found between both stall length and sow length and the time taken by sows to move from a standing to a lying posture. Stall width and sow breadth and the time taken by sows to change from standing to sitting were also negatively correlated. Cariolet et al. (1997) reported that sows housed in wider gestation stalls were able to achieve full recumbency more than sows housed in narrower gestation stalls. The commercial gestation stall is long and tall enough to house the contemporary sow, however, increasing stall width or designing a stall that could accommodate the changing size of the pregnant sow would greatly improve freedom of movement.

Another issue that stems from the concern over freedom of movement is whether or not the gestating sow would have better welfare if it was kept in a group pen or pasture, and not in an individual gestation stall. Therefore, it would be free to display various behaviors such as walking, turning, and foraging, all of which are not possible in a standard gestation stall. However, the appropriate amount of space needed per sow when in a group housing system during gestation has not been adequately investigated. The objective of a study at the University of Illinois was to compare the impacts of floor-space allowance (14.8 ft^2, 24.3 ft^2, or 34.8 ft^2 per sow) on performance, body lesion score, and body condition score. The individual gestation stall and group pens were also compared (Salak-Johnson et al., 2007). Although BW was generally greater for sows kept in pens, BW of sows housed in stalls or in 14.8 ft^2 pens was within the acceptable range. Moreover, sows kept in pens, regardless of size, had greater lesion scores than sows kept in stalls. However, both sow BW and back fat increased in a linear fashion as floor space was increased. Litter size, litter weaning BW, piglet weaning BW, and birth-to-weaning BW gain also had positive linear trends with floor space allowance (Salak-Johnson et al., 2007). Both the standard gestation stall and group pens have their advantages and disadvantages.

Impact of the Gestation Stall on Sow Welfare: Behavior

Individual housing accommodation options for the gestating sow consist of the standard gestation stall, neck and girth tether stall, and turn-around stall. While all three stalls generally receive criticism for the limited space they offer, numerous studies have shown that tethered sows have compromised welfare (Barnett et al., 1987, 1989, 1991; McGlone et al., 1988, 1994). Although the use of tether stalls is declining, it is worthwhile to discuss some of the research on this particular housing system as it highlights some interesting findings concerning the effects of stall design on behavior.

Earlier research that focused on the design of the tether stall divisions (vertical bars or bars covered in steel mesh) found that stall design can affect the number of aggressive interactions between neighboring pigs (Barnett et al., 1987a, 1987b). The modified tether stall design (bars covered with steel mesh), reduced the number of aggressive interactions from an average of 9.8 to 2.7 per pig during 160 minutes of observation (Barnett et al., 1987). Likewise, the design of the standard gestation stall was also found to affect sow behavior. Barnett et al. (1989) compared two kinds of housing (standard gestation stall and tether stall), each with two different types of stall divisions (bars or mesh). Sows in each type of stall with a mesh division showed lower levels of aggression, compared to sows that were housed in stalls with bar divisions. However, physiological data indicated that pigs in the unmodified tether treatment showed evidence of a chronic stress response, while the design of the standard stalls had no effect on physiological responses. Therefore, this study concluded that the standard stall, regardless of design, does not negatively affect sow welfare.

More recent research has shifted focus to the direction of the bars used in the standard stall (Barnett et al., 1991). Barnett et al. (1991) compared the design of the standard stall (vertical bars or horizontal bars), with two control treatments, tether stall (vertical bars) and group housing. Sows housed in the standard stall with horizontal bars engaged in fewer aggressive interactions with neighboring sows, and durations of interactions were shorter than sows housed in the vertical stall treatment. However, physiological data indicated a chronic stress response for sows housed in the standard stall with horizontal bars. Sows housed in the standard stall with vertical bars had similar cortisol concentrations to group-housed pigs, and had lower levels than tethered pigs and pigs in the standard stall with horizontal bars. However, pigs housed in the standard stall with vertical bars showed the highest levels of aggression compared to all other treatments. In this study, hormone data was not correlated with behavior data, thus further research is needed to assess the relationship between social behavior physiological responses.

The type of individual stall has been reported to also affect stereotypic behavior measures. McGlone et al. (1994) compared the reproductive performance, behavior, immunity, and ergonomics for the girth tether and standard stall (horizontal bars). Sows and gilts housed in the standard gestation stall were, overall, more active than girth-tethered sows. Girth-tethered sows spent more time lying than sows housed in standard stalls. Parity had an effect on lying behavior and total active behavior; however the relationship between treatment and parity was not significant. Sows housed in the standard stall showed elevated drinking, sitting, and ONF behavior, but it is important to note that girth-tethered sows did not have a bar in front of them to bite, chew, or rub. Although sows housed in the standard stall displayed more stereotypies, they had an increase in litter size born and litter birth weight from the first to second parity. Girth-tethered sows had a reduction in litter size born and total birth weight from the first to second parity. As mentioned in section 2.2 above, it is possible that stereotypies may serve as a coping mechanism to help reduce stress. Wiepkema et al. (1987) found that calves that had developed tongue-rolling (33 percent of subjects) had less abomasal damage and no ulcers or scars. All of the calves that did not develop tongue-rolling (67 percent of subjects) did have ulcers or scars. The data from McGlone et al. (1994) confirms that ONF stereotypies may be beneficial. Sows housed in the standard gestation stall showed no evidence of stress, and McGlone et al. (1994) recommended that the practice of girth-tethering sows be discouraged on commercial farms.

One housing system that is a compromise between the standard gestation stall and group pens is the turn-around stall. The turn-around stall was configured in part to address public concern about the lack of freedom of movement. Bergeron et al. (1996) compared the standard gestation stall to the turn-around stall and found that gilts in turn-around stalls stood more frequently than gilts in standard stalls. Gilts in turn-around stalls also manipulated a chain (ONF behavior) twice as much as gilts housed in standard stalls. This suggests that ONF behaviors are not caused by the lack of opportunity to turn around. Moreover, because ONF behavior is often classified as stereotypic behavior, this specific study may indicate that gilts in turn-around stalls were more stressed than gilts in standard stalls. McFarlane et al. (1988) examined turning and walking behavior of gilts kept in stalls of different design. In experiment one, flared stalls were the same length (2.1 m), had a center width of either 56 cm or 61 cm, and widened to either 112 cm or 122 cm at the end. The stalls used in experiment two had different lengths of either 2.1 m or 3.4 m, were the same width at the center (61 cm), and both ends were either flared (widening to 122 cm in width) or rectangular. Gilts from experiment one, kept in stalls with a lesser width in both the center and at the flared ends, turned >30 percent less than gilts housed in the wider stalls, suggesting that a gilt's motivation to turn around may not be a strong behavioral need. The distance that gilts moved in experiment two, did not decrease when crates were flared as opposed to rectangular. On the other hand, turning frequency did not decrease when flared crates were lengthened. This suggests that gilts may not turn around to gain physical exercise, but perhaps to just face the other direction. It is still not clear from studies whether the greater freedom of movement utilized in the turn-around stall actually improves sow welfare.

For the gestating sow, there is much debate over whether individual housing in stalls causes more stereotypic behavior compared to other housing accommodations (turn-around stall, tether stall, group housing systems, etc.). In the assessment of sow welfare, and adaptation of sows to different housing accommodations, the durations and frequencies of non-eating ONF behaviors have been measured. Stereotypic behavior is commonly thought to be associated with keeping sows in barren environments (Whittaker et al., 1998). However others believe that stereotypies are influenced by substrate availability (McGlone et al., 2004b). Dailey and McGlone (1997) examined ONF behavior in three housing systems: pasture, soil, or gestation crates. Sows in all environments performed similar frequencies of total ONF behaviors during a 24-hour period. Sows on pasture chewed grass; soil-kept sows chewed rocks and soil; and crated sows chewed the bars. All sows displayed ONF behavior on the substrate that was available to them, suggesting that sows are highly motivated to perform ONF behaviors regardless of their housing system. The nature of the motivation may differ among the three environments (Dailey & McGlone, 1997). However Vieuille-Thomas et al. (1995) found that indoor group-housed sows displayed less stereotypic behavior than both stall-housed and tethered sows during the one hour following feed distribution. Stall-housed sows and tethered sows developed similar levels of stereotypies. Blackshaw and McVeigh (1984) examined pre-feeding and post-feeding behavior in group- housed sows, stalled sows, and neck-tethered sows, and found that group-housed sows showed less pre-feeding stereotypic behavior and no post-feeding stereotypic behavior.

Research also suggests that stereotypies may be associated with limited feeding and lack of opportunity for foraging, rather than restriction of movement (Fraser & Broom, 1997; Lawrence & Terlouw, 1993; Terlouw et al., 1991; Terlouw & Lawrence, 1993). Gilts on a restricted diet have been shown to develop oral stereotypies when housed in loose pens or by tether, while gilts fed a larger amount of feed housed in those same two environments showed little tendency to develop stereotypies (Terlouw & Lawrence, 1993). This suggests that feed restriction can cause development of oral stereotypies regardless of housing systems, conflicting with the notion that stereotypies are caused specifically by the tethering system or restriction of movement.

Impact of the Gestation Stall on Sow Welfare: Productivity and Performance

Production measures such as BW, BW gain, and reproductive output are also welfare indicators (Broom & Johnson, 1993). Interruptions in growth rate or fluctuation of BW are indicators that an animal may not reproduce, may be ill, or may live a shorter time than deemed normal (Broom & Johnson, 1993). For the gestating sow, an increase in BW is expected, thus an interruption of growth rate or loss of BW could indicate that the sow is stressed, ill, or that there is possibly a problem with its pregnancy. However, because animals have developed coping mechanisms to adapt to real or perceived challenges, environmental conditions must be quite poor before the animal's biological fitness, i.e. the animal's abilities to successfully survive, grow, and reproduce, is affected (Broom & Johnson, 1993; Fraser & Broom, 1997).

Sow BW and BW gain are often assessed when evaluating sow welfare in different housing systems. Salak-Johnson et al. (2007) compared the effects of housing sows in pens or in individual stalls, and found that although BW was greater in sows kept in pens, the BW of sows kept in stalls or in 1.4 m^2 pens was within the respective range of commercial industry norms. Harris et al. (2006) found no overall effect of housing (individual stall or small group pen) on the amount of weight that gilts gained during gestation. Estienne and Harper (2010) also reported similar BW at the end of gestation for gilts kept in either stalls throughout the entire gestation period or for the first 30 days of postmating and then group pens, and for gilts kept in group pens throughout gestation. However, Backus et al. (1997) found that sows kept in a free-access stall system had a greater weight at the end of gestation than sows kept in groups with electronic sow feeders (ESF), trickle-feeding group system, and individual stalls.

In addition to the assessment of sow BW and BW gain, reproductive traits are commonly evaluated in differing housing systems. A comprehensive review of the scientific literature indicates that housing conditions (individual stalls or groups with electronic feeding) have no effect on litter size (McGlone et al., 2004b). Backus et al. (1997) found no differences in the average number of live-born pigs per litter for the stall, free-access stall system, ESF group system, and the trickle-feeding group system. Harris et al. (2006) reported no differences in reproductive performance between gilts housed in stalls compared with small groups during gestation. However, Kongsted (2005) found that gestating sows housed in groups had greater reproductive impairment as indicated by a greater re-breeding rate, reduced litter size, and lower pregnancy rate, compared to stall-housed sows. Estienne and Harper (2010) reported a greater number of pigs born alive for sows housed in crates throughout the entire gestation period or in crates for the first 30 days postmating and group pens for the rest of the gestation period, compared to gilts kept in group pens throughout gestation. Cronin et al. (1996) found that the proportion of pigs alive at day 8 post-partum was higher for sows that gestated in stalls than in groups. Barbari (2000) reported a trend for both an increased number of pigs born alive and weaned among farms that housed sows in stalls rather than in group systems. In another study, the number of live-born pigs was higher for sows housed in individual stalls than for tethered and group-housed sows (den Hartog et al., 1993). Live-born pigs from group-housed sows had a significantly lower average birth weight than did the pigs of the individually housed sows. Moreover, sows housed in individual stalls had the lowest replacement rate during the experimental period compared to group-housed sows and sows housed by tether. However, Bates et al. (2003) reported similar or improved performance (e.g., higher litter birth weights) among sows that gestated in a group system with ESF when compared to sows in stalls, but no effect on the number of pigs born alive or weaned. However, sows housed in stalls had heavier litter wean weights at the end of lactation (Bates et al., 2003). Differences in management practices across farms, make it difficult to assess productivity measures. However, based on previous scientific assessments, sows housed in stalls and well-managed pens generally have similar productivity levels.

Performance measures such as skin lesions or sores are also evaluated to assess sow well-being. Lesions can be indicative of aggression or housing design flaws and are thus measured not only among group-housed sows, but also in stall-housed sows. Numerous studies indicate that group-housed sows have greater lesion scores than sows kept in stalls (Anil et al., 2003; Backus et al., 1997; Estienne et al., 2005; Gjein & Larssen, 1995; Harris et al., 2006; Karlen et al., 2007;

Salak-Johnson et al., 2007). Karlen et al., (2007) reported that the welfare challenges for group-housed and stall-housed sows may change over time. For example, during the early gestational period, sows in large groups have an increased incidence of scratches, whereas stall-housed sows have a higher incidence of lameness and abrasions as the gestational period progresses.

Anil et al. (2005) found that the total injury score at all stages of gestation was lower in stall-housed sows than in group-housed sows. However, stall-housed sows had a significantly higher total injury score during the later stages of gestation compared to all other stages of gestation (Anil et al., 2005). Stall-housed sows had an increased prevalence of injuries on the top of the back, forelimbs, hind limbs, and udder as gestation advanced, which was attributed to an increase in body size associated with the developing pregnancy and consequent reduction of space availability and limited freedom of movement. An earlier study conducted by Anil et al. (2002) suggested that injuries on the top of the back result from the back of a sow being pressed against the bars on the sides of the stall when the sow is in lateral recumbency.

Anil et al. (2002a) evaluated the relationship between injuries and the size of gestation stalls relative to the size of sows. This study found that larger sows, relative to stall length or width, had greater injury scores and that the relationship between stall length to animal length and stall width to animal width was responsible for approximately one-fourth of injuries sustained by stall-housed sows (Anil et al., 2002a). Although some injuries may have been caused by other factors such as type of floor, sharp edges on the stall and feeder, and aggression between adjacent sows, it was suggested that increasing the width of stalls may help reduce or prevent injuries and thus improve the well-being of larger sows.

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Chapter 3: A Pilot Study on the Productivity and Behavior of the Gestating Sow Housed in a Flex Stall

Introduction

One of the most controversial issues facing the swine industry today is how the gestating sow ought to be accommodated in commercial pork production process. The use of gestation stalls (or crates), 2-x 7-foot enclosures used to house pregnant sows, are being continually criticized by animal activists, causing a growing concern among the general public about sow housing systems, and more specifically sow welfare. In accordance with European trends, Arizona, California, Florida, and Michigan have banned sow stalls through voter referendums and ballots, while Colorado, Maine, and Oregon have banned stalls through legislative initiatives (Springsteen, 2009). These bans have led to research and examination of alternative housing systems, the most common being group pens.

Many scientific evaluations indicate that the level of sow welfare is similar, whether sows are kept in individual stalls or group pens (Barnett et al., 2001; CAST, 2009; McGlone et al., 2004b). Both stall-housed and group-housed sows have similar mean values across all measures, from both a biological and statistical perspective. All sow housing systems currently used have apparent benefits and disadvantages, and no one system has been clearly identified as being better than another for sow welfare (Barnett et al., 2001; Gonyou, 2007; Levis, 2007; McGlone et al., 2004b; Rhodes et al., 2005; Salak-Johnson et al., 2007; Stalder et al., 2007).

With previous research indicating few direct correlations between housing systems and improved sow well-being, it is essential that researchers focus on the advantages of current housing systems, as well as identify existing problems and opportunities for improvements. Improvements in the individual gestation stall system, such as increasing stall width or designing a stall that could accommodate the changing size of the pregnant sow, may improve sow welfare. McGlone et al. (2004a) found that the physical dimensions of sows vary not only within groups of sows at the same location, but also between sows from different farms. Research also indicates that sow body depth increases an average of .12 cm per day from d 23 to 115 of gestation (McGlone et al., 2004a). This means that a sow is approximately 12.7 cm deeper, from back to udder, at the end of pregnancy. The physical size of the commercial gestation stall may limit movement and evoke demands and challenges that affect the physiological and psychological well-being of the sow. If the physical limitations are compensated by an adjustable stall and the freedom to move, sow welfare may be improved. Therefore, the objective of this pilot study was to evaluate the effects of an adjustable stall on productivity and behavior of the individually housed sow.

Materials and Methods

Animals, Housing, and Experimental Design

York crossed, multiparous sows kept at the University of Wisconsin Swine Research Center were used to compare the effects of housing sows in an individual width adjustable stall (FLEX) or individual standard stall during pregnancy. Sixteen sows were allotted to 1 of 2 treatments based on body weight (BW). Large sows had an average BW of 234 kg and small sows had an average BW of 174 kg, and an equal number of large sows and smalls sows were dispersed throughout the two treatment groups. The experiment consisted of 3 replications (block 1, 4 sows; block 2, 4 sows; block 3, 8 sows) and an equal number of sows in each replication were allotted to 1 of 2 treatments for 1 gestation period. The gestational time periods for each block of sows are presented in Table 1.

FLEX stall was designed by John Kane in collaboration with the University of Wisconsin and is not commercially available. FLEX stall allows space at the sow's critical location (midsection) throughout gestation and provides flexibility for adjustments to individual sows within a row of stalls. The center width of each FLEX stall was adjusted according to the sow's changing BW and dimensions. The standard gestation stall was 61 cm wide. Both the FLEX stall and standard gestation stall were 216 cm long and the front gate and sides of each type of stall were equipped with vertical bars (Figure 1).

Sow mid-girth (top of the back to bottom of the udder) was measured 5-6 times throughout gestation (Table 2) to determine the best time points for FLEX stall width expansions. The goal was to adjust FLEX stall width according to mid-girth, so that sows could lie in full lateral recumbency without touching the sides of the stall. Based on sow mid-girth measurements, FLEX stall width was expanded to achieve an additional 2 cm of space between the bottom of the sow's udder and floor of the stall.

Before the study, all sows were kept in standard gestation stalls after their previous litters were weaned. Sows were inseminated within 24 hours after estrus and again 24 hours later. Pregnancy was confirmed d 21 (blocks 1 and 2) or d 28 (block 3) via abdominal ultrasound, and then sows that were pregnant were moved to their respective assigned treatments. Sows remained in their respective gestation treatment groups until approximately d 112 of gestation, when they were moved to the farrowing facility.

Sows were kept in a well-insulated, mechanically ventilated, closed barn during the breeding and gestation periods. During winter months, the facility was kept at an average temperature of 64 °F. Sows were individually fed a diet in which nutrient concentrations met or exceeded current requirement estimates (NRC, 1998). During gestation, each sow was fed 1.9

kg/d of a corn-soy-based diet having a calculated composition (as-fed) of 12.6% CP and providing a calculated ME density of 3,423 kcal/kg. All sows were fed between 0630 and 0800 each day. Each stall had a water trough in front of it. Lactating sows were fed 5.2 kg/d of a corn-soy based diet with a calculated composition (as-fed) of 18.2% CP and 3,449 kcal of ME/kg.

Productivity and Performance Measures

Sow BW and BW gain were recorded on the same days that sow mid-girth measurements were made. Litter traits included number of piglets born and born alive, and proportions of piglets stillborn, mummified, lost between birth and weaning, and weaned. Litter and mean piglet birth BW, weaning BW, and average BW gain from birth-to-weaning were calculated.

Total number of lesions on the left and right sides of the body were recorded at the beginning of the experiment (d 21) and at the end of the experiment (d 111).

Behavioral Measures

Behavior was recorded for sows in replicate 1 (n=4) using a Geovision GV-1240 video capture combo card and viewed using EZViewLog500 in real-time. Behavior was observed and registered for the l2 hour lights on period (period 1, 0600-1000; period 2, 1000-1400; period 3, 1400-1800) prior FLEX stall adjustment and 12 hour lights on period post adjustment on d 21, 22, 23, 43, 44, 45, 93, 94, 95. The behaviors registered and analyzed using continuous sampling included: oral-nasal-facial (ONF), sham-chew, sit, stand, lay, lay (IN), lay (OUT), eat, drink, and postural changes (Table 3). Durations of all behaviors were assessed, with the exception of postural changes which were evaluated by frequency.

Statistical Analysis

Sixteen sows were used in a randomized complete block design with a 2 × 2 factorial arrangement of the treatments to analyze sow productivity and performance traits. The model included fixed effects of stall (FLEX or standard), sow size (large or small), and stall x sow size interaction. A random effect of block (sows in replicates 1-3) was included in the model to account for potential environmental and management differences across sows housed in individual stalls. The experimental unit was sow because productivity and performance traits corresponding to stall type were from a single sow or experimental unit per stall. Normal distribution of residuals and homogeneity of variances were tested and assumptions for analysis of variances were fulfilled. It was assumed that there was no interaction between block and stall, and block and sow size. Standard error of the mean (SEM) values are associated with least squares means as calculated in the Mixed Models procedure. Differences among means with a P-value of less than 0.05 were considered significant, and P-values greater than 0.05 but less than or equal to 0.10 were considered trends. Data were analyzed using the Mixed Models procedure of SAS/STAT® software, version 9.2 for Windows® (SAS Institute Inc., Cary, NC). A preliminary analysis of data means and numerical trends was used to analyze sow behavior measurements. Behavioral observations for replicates 2 and 3 are still in progress, thus, the entire data set is not complete yet to do a valid statistical analysis.

Results

The interaction effect of stall × sow size for productivity and performance traits data are presented in Table 4. There were no stall × size interactions for sow BW gain, total born, live born, still born, average piglet birth weight, and number weaned. Only one sow gave birth to a mummy, thus mummies were excluded from the statistical analysis. There was a stall × sow size interaction ($P = 0.005$) for average piglet BW gain. Large sows housed in a FLEX stall and small sows housed in a standard stall had higher ($P < 0.05$) average piglet BW gain than small sows housed in a FLEX stall. Large sows housed in a standard stall had an intermediate average piglet BW gain which was not different than any of the other treatments. There was also a stall × sow size interaction ($P = 0.03$) for average piglet weaning weight. Results followed the same trend and large sows housed in a FLEX stall and small sows housed in a standard stall had higher ($P < 0.05$) average piglet weaning weight than small sows housed in a FLEX stall. There was a trend for a stall × sow size interaction ($P = 0.06$) for number of piglets lost from birth to weaning. Large sows housed in a FLEX stall had a higher ($P < 0.05$) number of piglets lost than large sows housed in a standard stall and small sows housed in a FLEX stall. Smalls sows housed in a standard stall exhibited an intermediate value which was not different than the rest of the treatments. There was also a trend for a stall × sow size interaction ($P = 0.10$) for lesions.

Type of Stall Effects on Productivity and Performance

Probability values and means for type of gestation stall effects on sow productivity and performance are presented in Table 5. Total born was affected by stall type ($P = .006$). Sows housed in a FLEX stall had more total born than sows housed in a standard stall. There was a statistical trend ($P = 0.06$) for live born to be higher for sows housed in a FLEX stall compared with sows housed in a standard stall. As expected, sow BW gain followed the same trend ($P = 0.06$) as live born, as this was probably due to those sows having more live born. Although, live born and sow BW gain were not statistically significant, they would most likely become so with a higher number of replications.

Sow Size Effects on Productivity and Performance

As expected, there was a statistical trend ($P = 0.07$) for larger sows to have more total born than smaller sows (Table 6). Average piglet weaning weight tended ($P = 0.10$) to be more for larger sows than smaller sows.

Type of Stall Effects on Behavior

Mean durations for type of gestation stall effects on sow behavior are presented in Table 7. There were numerical trends for mean durations of sit, lay, lay (OUT), and eat behaviors to be greater for sows housed in a FLEX stall compared with sows housed in a standard stall. The mean duration of lay (IN) tended to be numerically less for sows housed in a FLEX stall compared with sows housed in a standard stall. There was a numerical trend for the mean durations of stand and drink behaviors to be greater for sows housed in a standard stall compared with sows housed in a FLEX stall. The mean frequencies of postural changes and mean durations of ONF and sham-chew behaviors were numerically similar between types of gestation stall.

Time of Day Effects on Behavior

Mean durations and numerical trends indicate that time of day influenced all of the behaviors assessed in this study (Table 8). There were numerical trends for mean durations of stand, eat, and drink behaviors to be greater during time period 1 (morning) compared with time periods 2 and 3 (late morning to early evening). This was expected, as sows were fed during time period 1. There was also a numerical trend for the mean durations of ONF to be greater during time period 1 compared with periods 2 and 3.

Mean durations of lay, lay (IN), and lay (OUT) tended to be numerically lower during time period 1 compared with time periods 2 and 3. Sows tended to sit the least during time period 3. There was a numerical trend for the mean duration of sham-chew to be greater during time period 2 (late morning to early afternoon) compared with time periods 1 and 3 (morning; afternoon to early evening). The mean frequencies of postural changes decreased from time periods 1 to 3.

Discussion

The results of the pilot study reported herein indicate that the design of the gestation stall (FLEX or standard) affects productivity and performance measures of the gestating sow. Preliminary behavioral data suggest that with an increased sample size and additional behavioral observations, several behavioral traits will likely be affected by stall type. Although the sample size for productivity and performance measures (n=16) was also relatively small, a few measures were statistically significant. It can be speculated that several of these measures may reach statistical significance with an increased number of replications, however, caution must be taken in interpretation of these results as some of the differences detected may have been due to a random effect.

A comprehensive review of the scientific literature indicates that current housing conditions in use (individual stalls or various group housing systems) have no effect on litter size (McGlone et al., 2004b). Backus et al. (1997) found no differences in the average number of live-born pigs per litter for the stall, free-access stall system, ESF group system, and the trickle-feeding group system. Harris et al. (2006) reported no differences in reproductive performance between gilts housed in stalls compared with small groups during gestation. However, Kongsted (2005) found that gestating sows housed in groups had greater reproductive impairment as indicated by a greater re-breeding rate, reduced litter size, and lower pregnancy rate, compared to stall-housed sows. Estienne and Harper (2010) reported a greater number of pigs born alive for sows housed in crates throughout the entire gestation period or in crates for the first 30 days post-mating and group-pens for the rest of the gestation period, compared to gilts kept in group-pens throughout gestation. Thus, it is of great interest that in this experiment sows housed in a FLEX stall had even better reproductive performance than sows housed in a standard gestation stall. However, embryonic failure and return to estrus, two major factors associated with reproductive performance, were not measured in the current study (Christianson, 1992; Vargas et al., 2009). Future work should continue to assess reproductive traits of sows housed in a FLEX stall and perhaps additionally measure embryonic failure as well as return to estrus.

One of the goals of this experiment was to assess whether the FLEX stall affected large and small sows differently. Parity was not included in the model because some of the large and small sows were of the same parity. Small sows housed in a standard stall may have had higher average piglet BW gain and higher average piglet wean weight compared to small sows housed in a FLEX stall because there was a numerical trend for those sows to have less live born. Milligan et al. (2002) found that piglet mean weaning weight was highest in litters with fewer live piglets. Although there was a numerical trend for large sows housed in a FLEX stall to have the most live born and the highest average piglet BW gain and average piglet wean weight, those sows also had the highest number of piglets lost. Sows with larger litters produce more milk, however, the extra milk produced is not proportional to the number of extra piglets (Milligan et al., 2002). Previous research has found that piglets in larger litters miss more nursings, have lower teat consistency scores, and have more teat disputes than piglets in smaller litters (Milligan et al., 2001). Thus, it is not surprising that large sows housed in a FLEX stall had the highest number of piglets lost. However, it is also possible that the high number of piglets lost could have been caused by maternal crushings or overlying of the sow. Andersen et al. (2011) found that piglet mortality caused by maternal crushing of piglets increased with increasing litter size. It also is worth noting that the behavioral results obtained from this study indicate that sows housed in a FLEX stall tended, on average, to sit more than sows housed in a standard stall. Perhaps when sows were moved to the farrowing stall, they continued to engage in a sitting posture because of their previous experience of being able to do so while in the FLEX stall. Moreover, it may be speculated that the sitting posture was correlated with piglet crushing mortality. The numbers of piglets born alive and lost to small sows housed in a FLEX stall and large sows kept in a standard stall were not different. Thus, those sows had piglets with similar average BW gain and similar average weaning weight. Average piglet birth weight was not different between large or small sows housed in either a FLEX or standard stall, thus, average piglet BW gain and average piglet wean weight had similar interactions.

One notable finding of this experiment was that the FLEX stall appeared to affect the presence of lesions in small and large sows differently. Although there were only numerical trends for these differences, a large standard error of the mean makes it likely that with more animals per treatment, statistical differences would have been detected. McGlone et al. (2004a) suggested that larger sows kept in a stall less than 57 cm wide may be in an uncomfortable position due to restricted stall width, while Curtis et al. (1989) estimated that a small sow weighing only 150 kg would require a dynamic physical space requirement wider than 60 cm. If dynamic space requirements are not met and a sow does not have the additional space needed to change postures, it is likely that the presence of lesions will increase. Small sows in this study were ≤ 203 kg at the beginning of the gestation period, with the majority of them weighing over 150 kg. Thus it makes sense that the additional space provided by the FLEX stall even benefited the smaller sows in this experiment. Based on the data collected, it is unknown why large sows housed in a FLEX stall had more lesions at the end of gestation compared to large sows housed in a standard stall. Perhaps, the FLEX stall had a design flaw (i.e. bolt sticking out from the area that could be adjusted) that was causing lesions. Another potential explanation is that the presence of lesions varied among sows on d 21 of gestation. Future work should ensure that the presence of lesions does not differ between sows at the beginning of the gestation period.

Despite the benefits of the individual gestation stall, there is much public concern about how much space the gestating sow needs before its welfare is compromised. Freedom of movement, and thus behavioral needs, are of particular concern. Research has shown that multiple factors, such as parity, BW, and stage of gestation have been reported to influence the gestating sow's body size (McGlone et al., 2004a). In this study, however, the FLEX stall was adjusted to accommodate the sow's changing BW and dimensions. The sub-pilot behavior results obtained confirm previous reports (Barnett et al., 2001; McGlone et al., 2004b; CAST, 2009) indicating that housing design may influence some behaviors of the gestating sow.

Maintenance behaviors, i.e. behaviors which have obvious functions such as eating and drinking are essential to the sow's fitness, performance, and overall well-being. The observed difference in eating behavior was unexpected, as sows were individually and limit fed. Sows often exhibit ONF behavior post feeding, which can sometimes be difficult for human observers to distinguish between eating. Perhaps, the observed difference in this study was due to different data collection methods, as there were three behavioral data collectors for this experiment. It is also likely that the increased drink behavior amongst sows housed in a standard stall could have been partially due to different data collection methods. Although drink behavior in this study was defined as stationary contact with the snout/mouth to water in the trough, it can be difficult to determine when the sow's snout is actually touching the water or if the sow is engaging in

ONF behavior on the sides of the water trough. However, it is also possible that the increased drink behavior may have been linked to thermoregulatory processes. One theory suggests that stall-housed sows may need to rely more on varying feed and water consumption for thermoregulation because they are unable to engage in certain behavioral thermoregulatory processes such as huddling and altering their microenvironment (Verstegen & Curtis, 1988; Estienne et al., 2005; Salak-Johnson, 2007). It must also be noted that sows housed in a standard stall also tended to stand more than sows housed in a FLEX stall. Future research with an increased sample size and additional behavioral observations should perhaps investigate whether there is a correlation between stand and drink behaviors.

Sows in this experiment engaged in similar mean frequencies of postural changes, regardless of gestation stall. Anil et al. (2002) examined how the relationship between stall size and sow size affects postural behavior. Results of that study suggested that sows take more time to complete a postural change when the stall size is less relative to the sow's size. Negative correlations were found between both stall length and sow length and the time taken by sows to move from a standing to a lying posture. Stall width and sow breadth and the time taken by sows to change from standing to sitting were also negatively correlated. Future research concerning the effects a FLEX stall has on postural change behavior should perhaps assess postural change durations in addition to postural change frequencies. As in the experiment reported herein, sows should be allotted to stall type based on BW so the relationship between stall size and sow size could potentially be evaluated as well.

In this study, sows housed in a FLEX stall tended, on average, to sit and lie more than sows housed in a standard stall. One potential explanation for these findings is that sows housed in a FLEX stall could have simply been more comfortable in sitting and lying positions. Sows housed in a FLEX stall tended to lie with their legs out of the stall more than sows housed in a standard stall, while sows housed in a standard stall tended to lie with their legs in the stall more than sows housed in a FLEX stall. These findings were unexpected, as it is unclear why a sow with additional space would need to lie with her legs out of the stall. As one of the main criticisms of individual gestation stall housing is its available space, animal protection organizations often argue that a sow must be in an uncomfortable position if her legs are lying out of the stall while she is in full lateral recumbency. In this study, it is interesting that the sows provided with additional space lay with their legs out of the stall. Perhaps, sows kept in a FLEX stall had perceived that they had more room and therefore didn't feel the need to press their backs up against one side of the stall. Moreover, it is possible that those sows may have been lying directly in the middle of the stall, therefore causing their legs to stick out. Or, perhaps sows housed in a FLEX stall were lying with their legs out of the stall and on their side for thermoregulatory purposes. It could be speculated that the extra space provided by the FLEX stall allowed sows to engage in a behavioral response to help regulate their body core temperature. An altered lying posture, such as spreading out, would increase body surface area and result in a cooler microenvironment for that sow.

For the gestating sow, there is much debate whether individual housing in stalls causes more stereotypic behavior compared to other housing accommodations. Stereotyped behavior is most commonly defined as "a repeated, relatively invariate sequence of movements which has no obvious purpose" (Broom & Fraser, 2007). The two most common stereotypic behaviors displayed by the gestating sow are ONF and sham-chewing. Stereotypic behavior is commonly thought to be associated with keeping sows in barren environments (Whittaker et al., 1998). However others believe that stereotypies are influenced by substrate availability (McGlone et al., 2004b). Dailey and McGlone (1997) examined ONF behavior in three housing systems: pasture, soil, or gestation crates. Sows in all environments performed similar frequencies of total ONF behaviors during a 24-hour period. All sows displayed ONF behavior on the substrate that was available to them, suggesting that sows are highly motivated to perform ONF behaviors regardless of their housing system. In the present study, the mean durations of ONF and sham-chew behaviors were numerically similar between types of gestation stall. Although, both types of stalls were similar environments, it is noteworthy that the additional space provided by the FLEX stall did not decrease stereotypic behavior. The results of this experiment agree with those of Dailey and McGlone (1997) and suggest that sows may be highly motivated to perform ONF behavior regardless of their housing system.

In this study, time of day appeared to influence all maintenance behaviors and even stereotypic behavior. All sows, regardless of type of stall, tended on average to stand, eat, and drink, more during time period 1 than in time periods 2 and 3. This was expected, as sows were fed during time period 1. Sows also tended to display, on average, more ONF behavior during time period 1 compared to time periods 2 and 3. Dailey and McGlone (1997) concluded that ONF behaviors may be natural pre- and post-feeding appetitive and post-consummatory activities for sows (regardless of housing accommodations) that are limit fed. Thus, the high durations of ONF behavior observed during time period 1 of this study agree with previous research and were expected.

Sows tended, on average, to sham-chew more during time period 2 compared with time periods 1 and 3. Perhaps, this was because sows engaged in more ONF behavior during time period 1 and became less active during time period 3. When sows are housed in individual stalls, the availability of environmental features, such as the physical design of the stall can influence stereotypic behavior. In this experiment, both types of stalls were equipped with vertical bars, as opposed to horizontal bars. Perhaps, sows develop alternative stereotypies such as sham-chewing because they are unable to bar-bite. In assessing animal welfare, the significance of the development of alternative stereotypical behaviors in terms of motivation is unclear (CAST, 2009).

The mean durations of lay behavior were the lowest during time period 1 compared with time periods 2 and 3. This was expected, as sows tended to stand the most during time period 1. Sows tended to sit the least during time period 3. This was likely because sows tended to lie more as the day progressed. In accordance with sit and stand behaviors decreasing as the day advanced, the mean frequencies of postural changes decreased from time periods 1 to 3.

Implications

Several scientific evaluations have concluded that sow welfare is similar whether sows are kept in individual stalls or group pens (Barnett et al., 2001; CAST, 2009; McGlone et al., 2004b). Therefore, it is of interest that results from this study indicate that sows housed in a FLEX stall had improved productivity compared to sows housed in a standard stall. Sub-pilot behavioral data results suggest that some behaviors may be influenced by the FLEX stall, however, stereotypic behaviors were similar in both housing environments.

Although implementation of the FLEX stall system would take up more space than the standard gestation stall system, results of the current study indicate that it may be advantageous for swine producers to house their largest sows in FLEX stalls. FLEX stalls could conceivably be placed at the ends of rows of stalls or in a designated area of the barn so that entire housing systems wouldn’t need to be converted. Furthermore, swine producers in the European Union are currently being required to convert all individual stall housing systems into group housing systems by the end of 2012 (Peet, 2011). Legislation is going to require that sows are housed in groups for all but the first 30 days of gestation. Perhaps, the FLEX stall could be considered a desirable alternative housing system for European swine producers to use during that period.

While there are both positive and negative aspects associated in all systems currently used (Barnett et al., 2001; Gonyou, 2007; Levis, 2007; McGlone et al., 2004b; Rhodes et al., 2005; Salak-Johnson et al., 2007; Stalder et al., 2007) the results of this study indicate that future work should continue to compare the new and refined FLEX stall to current housing systems in use. It is essential that future research additionally assesses the ease and practicality of managing sows in the FLEX stall system so that the amount of time required for adjustments can be included in any related management decisions. Moreover, the overall welfare of the gestating sow cannot be accurately assessed or defined by any one specific measurement, thus future research examining the effects of the FLEX stall should use a multi-faceted approach and examine physiological and immune traits in addition to productivity and behavior.

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Tables

Table 1. Approximate gestational periods for each block of sows

Block	Gestation Period
1	September to December
2	December to April
3	April to July

Table 2. Mid-girth measurements throughout the gestational period for each block of sows

Block 1	Block 2	Block 3
Day 22	Day 22	Day 29
Day 44	Day 45	Day 51
Day 65*	Day 72*	Day 77
Day 84*	Day 96	Day 89*
Day 94	Day 112 (moved to farrowing facility)	Day 104
Day 111 (moved to farrowing facility)		Day 112 (moved to farrowing facility)

* no expansion necessary

Table 3. Ethogram

Behavior	**Description**
Oral-nasal-facial (ONF)	Any contact with the snout/mouth with an inanimate object excluding food or water
Sham-chew	Continuous chewing while no feed or substrate is present in the mouth
Sit	Animal is supported primarily by rump and hind legs with front legs extended
Stand	Animal is supported by body mass via all four limbs
Lay	Not supported by any limbs. Full contact with ground.
Lay (IN)	Lying with all four limbs in the stall crate
Lay (OUT)	Lying with one or more limbs out of the stall
Eat	When feed is present, contact with the snout/mouth to the feed
Drink	Stationary contact with the snout/mouth to water in trough
Postural changes	Any major transition causing a change in the overall location or placement of the body mass within the stall. Lying-sitting-standing (visa versa)

Table 4. LSM for significant stall x sow size interactions for productivity and performance for sows housed in flex or standard stalls during gestation

	Gestation Treatment				*P*-value	SEM
	Large		Small			
Measure	Flex	Standard	Flex	Standard	stall x sow size	
Δ Lesions[1]	0.2	-7.8	-9.5	-1.0	0.10	6.33
Sow BW gain, kg	41.6	33.5	42.6	31.3	0.74	7.43
Total Born	15.5	11.8	13.0	10.8	0.41	0.87
Live Born	13.7	11.2	11.9	9.2	0.92	1.41
Still Born	1.8	0.5	0.8	1.5	0.31	1.0
Avg piglet birth wt, kg	1.6	1.8	1.5	1.5	0.71	0.17
Avg piglet wean wt, kg	8.1[a]	7.5[ab]	6.6[b]	7.7[a]	0.03	0.34
Avg piglet BW gain, kg	6.5[a]	5.7[ab]	5.1[b]	6.2[a]	0.005	0.25
Number Weaned	11.5	11.0	11.5	8.5	0.33	1.25
Number Lost	2.3_a	0.3_b	0.5_b	0.8_{ab}	0.06	0.53

[a-b]Within a row, means without a common superscript letter differ ($P < 0.05$)

[1] Change in the number of lesions was measured between d 21 and d 111

Table 5. Main effects of stall on productivity and performance for sows housed in flex or standard stalls during gestation (LSM)

	Gestation treatment		*P*-value	SEM
Measure	Flex Stall	Standard Stall	Stall type	
Δ Lesions[1]	-4.6	-4.4	0.96	5.48
Sow BW gain, kg	42.1	32.4	0.06	6.68
Total Born	14.3_a	11.3_b	0.0063	0.62
Live Born	12.8	10.2	0.06	1.09
Still Born	1.3	1.0	0.8	0.75
Avg piglet birth wt, kg	1.6	1.6	0.6	0.12
Avg piglet wean wt, kg	7.3	7.6	0.44	0.24
Avg piglet BW gain, kg	5.8	6.0	0.48	0.18
Number Weaned	11.5	9.7	0.18	0.91
Number Lost	1.4	0.5	0.13	0.37

[a-b]Within a row, means without a common superscript letter differ ($P < 0.05$)

[1] Change in the number of lesions was measured between d 21 and d 111

Table 6. Main effects of sow size on productivity and performance for sows housed in flex or standard stalls during gestation (LSM)

	Sow Size		*P*-value	SEM
Measure	**Large**	**Small**	**Sow size**	
Δ Lesions[1]	-3.8	-5.3	0.74	5.48
Sow BW gain, kg	37.6	37.0	0.9	6.68
Total Born	13.6	11.9	0.07	0.62
Live Born	12.4	10.5	0.17	1.09
Still Born	1.2	1.2	1.0	0.75
Avg piglet birth wt, kg	1.7	1.5	0.22	0.12
Avg piglet wean wt, kg	7.8	7.2	0.10	0.24
Avg piglet BW gain, kg	6.1	5.7	0.14	0.18
Number Weaned	11.2	10.0	0.33	0.91
Number Lost	1.3	0.6	0.26	0.37

[1] Change in the number of lesions was measured between d 21 and d 111

Table 7. Mean durations for type of stall on sow behavior in minutes (LSM ± SE)

	Gestation treatment	
Behavior	**Flex stall**	**Standard stall**
ONF	59 ± 14.9	62 ± 14.9
Sham-Chew	53 ± 15.3	49 ± 15.3
Sit	21 ± 12.8	7 ± 12.7
Stand	84 ± 26.5	105 ± 26.4
Lay	127 ± 8.7	110 ± 8.8
Lay (IN)	48 ± 8.4	94 ± 8.6
Lay (OUT)	72 ± 9	52 ± 13.4
Eat	32 ± 4.5	17 ± 4.2
Drink	3 ± 5.6	17 ± 5.5
Postural Change*	8.5 ± 2.2	9.5 ± 2.2

*frequency

Table 8. Mean durations for hour of day on sow behavior for sows housed in flex or standard stalls during gestation in minutes (LSM ± SE)

	Time of Day in Periods (seconds)		
Behavior	**1 (0600-1000)**	**2 (1000-1400)**	**3 (1400-1800)**
ONF	83 ± 12.2	62 ± 11.8	37 ± 11.4
Sham-Chew	38 ± 12.5	77 ± 12.1	39 ± 11.7
Sit	18 ± 10	16 ± 9.7	8 ± 9.5
Stand	158 ± 21.2	83 ± 20.9	38 ± 20.3
Lay	88 ± 12.2	130 ± 11.2	138 ± 9.4
Lay (IN)	58 ± 11.2	85 ± 9.9	71 ± 8.8
Lay (OUT)	47 ± 15	66 ± 14.2	73 ± 11.3
Eat	35 ± 2.6	14 ± 6.3	---
Drink	18 ± 4.5	10 ± 4.4	2 ± 4.4
Postural Change *	11.5 ± 1.8	9.3 ± 1.8	6.1 ± 1.7

*frequency

Figures

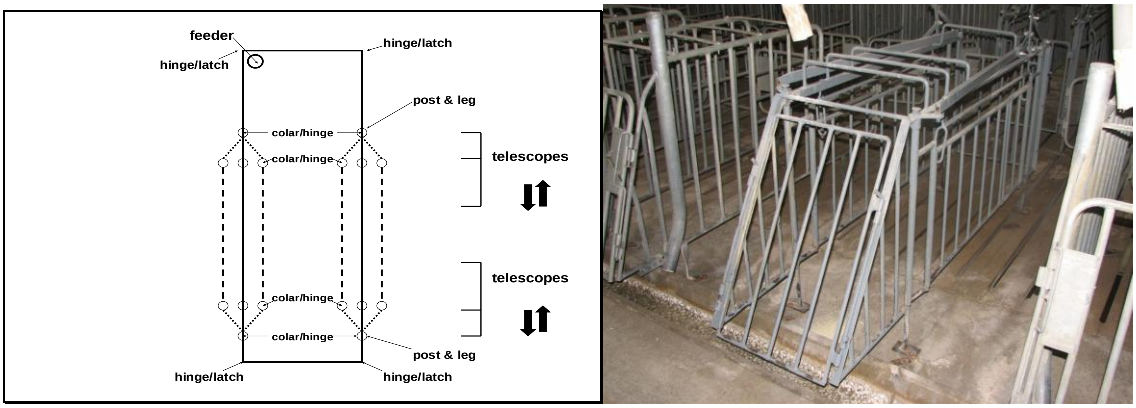

Figure 1. FLEX stall