SOCIAL FACTORS THAT AFFECT THE BEHAVIOUR AND PRODUCTIVITY OF GESTATING SOWS IN AN ELECTRONIC SOW FEEDING SYSTEM

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ABSTRACT

Previous research has shown that the productivity of sows housed in an Electronic Sow Feeding (ESF) system is affected by the housing management (static vs. dynamic), stage of gestation at mixing and parity. Familiarity has also been shown to affect the behaviour of group-housed sows. Thus, the objective of this experiment was to determine how the previously mentioned social factors affect the behaviour, physiology and productivity of sows housed in an ESF system. Sows were regrouped into either the static and dynamic pens. Within an introduction group, a subgroup of up to 24 focals sows was observed. The focal sows were chosen based on whether they were mixed pre vs. post-implantation (<12 vs. >46 days post-breeding), familiar vs. unfamiliar with group mates and parity (1st vs. 2nd and 3rd vs. 4th +). Aggression at mixing and at the feeder, injury scores, feeder entry order, space usage, salivary cortisol and farrowing productivity was recorded. The data was analyzed using Proc-Mixed and the General Model for SAS. Housing did not have a significant effect on the any of the parameters examined. Young sows had significantly more piglets born alive when housed in a dynamic system, while old sows had more piglets born alive when housed in a static system (p=0.03). Pre-implant sows initiated more aggressive encounters than post-implant sows (p=0.01). Post-implant sows ate later in the feeding cycle (p=0.03), rested on the slats more (p<0.001) and had higher salivary cortisol concentrations (p=0.0008). However, the cortisol concentrations increased throughout gestation for all sows (p<0.001). Familiarity did not have an effect on any of the variables examined except, familiar sows spent more time lying against the wall (p=0.03) and unfamiliar sows spent more time lying in the centre of the solid area of the pen (p=0.02). Old sows were involved in more aggressive encounters (p=0.04), spent more time fighting at mixing (p=0.02) and laid against the wall more (p<0.001). Young sows tended to received more scratches (p=0.07), ate later in the feeding cycle (p<0.001) and spent more time lying on the slats (p<0.001). Intermediate sows had significantly lower salivary cortisol concentrations (p=0.003). There was not a difference between the static and dynamic management systems. Sows should not be mixed until after embryonic implantation because they are more docile. The intermediate sows underwent the least amount of social stress due to their intermediate position within the dominance hierarchy.

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DEDICATION

I would like to dedicate this to my loving Nana and Papa, Joe and Ethel Young. I love you guys and I am proud to be your one and only granddaughter. Nana, even though you will never get to read this I know you are looking down on me and smiling.

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LIST OF ABBREVIATIONS

ESF	Electronic Sow Feeding System
NCCR	National Council of Chain Restaurants
$PGF_{2\alpha}$	Prostaglandin $F_{2\alpha}$
HPA	Hypothalamic-pituitary-adrenal
SNS	Sympathetic nervous system

1. INTRODUCTION

In 1965, the Brambell Report investigated the welfare concerns raised by Ruth Harrison's book "Animal Machines". The Brambell committee recommended that gestating sows not be housed in an environment that does not allow them to turn around freely, exercise daily and they should not be tethered when housed indoors. The industry is starting to recognize the importance of these recommendations made 40 years ago. Sow gestation housing has quickly become one of the most controversial topics in animal welfare.

The central debate in sow gestation housing is which system is more welfare friendly. The cause for the debate is that although switching gestating sows from stall to group housing systems alleviates some of the welfare concerns, a new set of welfare concerns arises with each type of group housing. Thus, until it is determined which of the negatives associated with each type of housing system is more detrimental to the welfare of the sows, the debate will continue.

There have been changes made within the industry. In the European Union, laws have been drafted to ensure producers comply with the changes desired by society. The regulations are based on scientific evidence that housing sows in stalls is associated with increased lameness, reduced muscle mass and bone strength (Marchant and Broom 1994, 1996a) and high rates of stereotypies (Edwards et al., 1999).

In 1999, the European Union created a directive that defined the minimum standards that must be met when raising swine. As of January 1, 2006, the use of tethers is no longer permitted and the length of time a gestating sow can be housed in a stall is limited to four weeks post-breeding and one week before farrowing in all newly built or renovated barns. As of January 2013, all barns within the European Union will have to meet the limitations previously mentioned (EU Directive, 2001). In the United Kingdom, the use of stalls to house gestating sows has been limited in all barns since January 1, 1999 (Garmoth, 2005).

In North America, sow gestation housing remains a controversial topic. However, there has not been as drastic measures taken to enforce changes in sow gestation housing. There is one exception, that being Florida, where the use of stalls for housing gestating sows has been banned since November of 2002 (Garmoth, 2005). As well, later in 2006, Arizona will be voting on whether or not to ban gestation stalls (Arnot and Gaudin, 2005).

The use of stalls as a method for housing sows during gestation is still acceptable in North America, but there are some changes that must be made in a stall housing system for it to remain acceptable. The National Council of Chain Restaurants (NCCR) has stated that stalls should permit a sow to lie in a stall without her teats extending into the neighboring stall. A stall should also provide a sow with enough room to stand up without difficulty. In terms of stall length, a sow's head should not rest in the feeder and her hind quarters should not be in contact with the back of the stall (NCCR, 2002). In a study by Li and Gonyou (2005), during the 14th week of gestation, the udder of sows housed in a 55 cm stall extended into the neighboring stall 91.7% of the time. During the 14th week of gestation, when the width of the stall was increased to 70 cm, a sow's udder extended into the adjacent stall only 23.5% of the time, when she was in a lateral position. To meet the requirements desired by the NCCR, stalls need to be made wider, as the typical stall in a commercial system is only 55 to 60 cm wide.

In Canada, there is the Recommended Code of Practices (CCAC, 1993). This document provides producers with the minimal criteria needed to raise pigs in a more welfare friendly manner. The problem is these are just recommendations and the producer can choose which recommendations to ignore or follow.

To settle the ongoing dispute of how the welfare of sows is affected by the type of housing system, more research is needed. When group housing of sows is studied, typically small groups (less than 20 sows per group) are examined. However, in grow/finish pigs, larger groups are not detrimental to animal welfare. Thus, this study examined the behaviour of sows fed using an Electronic Sow Feeding system, which typically has groups larger than most other systems. The behaviour and productivity of

sows housed in a static pen (approximately 35 sows) or a dynamic housing system (approximately 100 sows) was compared. Within each of the housing systems the affect that familiarity, stage of gestation at mixing and parity have on behaviour and productivity were examined.

2. LITERATURE REVIEW

2.1. History of Sow Gestation Housing

During the early part of the 20th century, the management of domestic pigs was pastoral. Traditionally, sows were housed outdoors, in large groups, unless a cool northern climate created the necessity for shelter (Svendsen and Svendsen, 1997). The intensive management systems currently in place were not developed until the 1960's and 70's, which is when technological advancements were incorporated into animal husbandry (Svendsen and Svendsen, 1997).

In terms of sow gestation housing, it was not until the mid-1960's that stalls and tethers came into common use. The Brambell Report (1965) referred to housing gestating sows in stalls or tethers as a recent development in intensive management practices. By the late 1970's, housing sows in stalls or tethers was quite common in Europe, but was still a relatively new management system in the United States (Belanger, 1977).

Before the intensification of swine production, the goal within the industry was to promote an harmonious relationship between maximizing animal growth and income while raising the animals in a manner that reflects their native roots (Dietrich, 1910). Though Dietrich was describing swine management at the beginning of the 20th century, the description is reflective of the natural definition of welfare described by Fraser and Duncan (1998).

2.2. Housing Systems

The intensification of swine management has led to the development of a wide variety of sow gestation housing systems. The following sections will describe the various types of sow gestation housing, and the pros and cons associated with each system.

2.2.1. Tethers and Stalls

In a tether housing system, the sows are housed in a partial stall. The sows are restrained within the stall by a collar, located around the sow's neck or midsection. The collar is attached to a chain secured to either the front of the stall or to the floor (Barnett et al., 2001). This type of restraint can be quite aversive to sows, as upon introduction sows have been observed to violently fight against the restraints (deKoning, 1984; Hansen and Vestergaard, 1984; Friend et al., 1988; Taylor et al., 1988; Brouns and Edwards, 1992). The sows' violent reaction to tethering causes lesions around the tethering site. When a tethered sow struggles on the concrete floors she also causes lesions on her hind feet (deKoning, 1984).

Tethers have become less popular, and it has become increasingly common to individually house sows in fully enclosed gestation stalls. The stalls are are typically only 55 to 60 cm wide and 220 cm in length. Sows housed within gestation stalls are unable to turn around and move freely.

There are advantages associated with tether and stall housing systems. The greatest benefits achieved by housing sows in stalls or tethers are the reduced aggression and greater control of individual feed intake (Gonyou, 1996; Barnett et al., 2001). Housing sows in stalls minimizes injuries to the body and vulva (Anil et al., 2002b), minimizes the amount the sows must be handled and simplifies health and pregnancy checks (Brouns and Edwards, 1992).

Despite the benefits of housing sows in stalls or tethers, there are numerous welfare issues associated with these two types of housing. One concern associated with housing sows in stalls or tethers is their inability to move freely and control their physical environment (Brouns and Edwards, 1992).

A good example of how the inability to move can be detrimental to the well being of sows is thermoregulation. The thermal comfort of stall-housed sows can be jeopardized when temperatures reach extremes. The domestic pig has difficulty maintaining its body temperature when they experience temperatures above the upper critical temperature. Compared with the wild boar, the surface area of skin per kilogram of body weight in domestic pigs is much smaller, which reduces the effectiveness of evaporative cooling (van Putten, 1988). Pigs also use evaporative cooling when they pant. However, the snout and larynx are much smaller in domestic pigs, thus reducing the effectiveness of panting (van Putten, 1988).

The behaviour of sows exposed to warm temperatures varies based on the type of housing system. As temperature rises, group housed sows increase the amount of time they spend lying laterally, and decrease the amount of time they spend lying on their sternum, while tethered sows are more active and drink more (Vestergaard and Hansen, 1984). An earlier study also found that as the body temperature of sows exposed to 40ºC temperatures rose, the sows increased their activity and their behaviour became erratic (Wildt et al., 1975). The increased activity during heat stress is counterproductive, as it increases the sow's body temperature. The increase in activity may have been how the stall housed sows expressed their frustration with being unable to cool off (Vestergaard and Hansen, 1984).

Lower body weights are another welfare concern associated with stall-housed sows (Barnett et al. 2001). In studies by Broom et al. (1995) and Marchant and Broom (1996a), the first parity sows housed in stalls weighed more than sows that were group housed. However, by the fourth parity, group housed sows weighed significantly more than stall-housed sows, even though the sows in both groups were kept on the same feeding regime.

The development of stereotypies is a concern associated with housing sows in stalls or tethers. Several studies have found that sows housed in stalls (Lambert et al., 1983; Arellano et al., 1992; Mendl et al., 1993; Morris et al., 1993; Broom et al., 1995 Chapinal et al., 2004) or tethers (Lambert et al., 1983; Hansen and Vestergaard, 1984) perform stereotypies at a higher rate than group housed sows. Vieuille-Thomas et al. (1995) did not find a difference in the rate that stall and tether housed sows performed stereotypies, but both performed stereotypies at a much higher rate than group housed sows. The development of stereotypies in stall housed sows may be how the sows cope with the frustration associated with their inability to move freely, forage, perform natural behaviours, and resolve aggressive encounters with neighboring sows (Broom et al. 1995). The increased bar biting performed by stall housed sows appeared to be how the sows coped with stress (Arellano et al., 1992).

Group housed sows also display stereotypies. However, they do so to a lesser extent than stall and tether housed sows. Group housed sows also perform stereotypies to cope with frustration, but the cause of the frustration is different than that of stall housed sows. Group housed sows tend to become frustrated because current methods of feeding do not allow the sow to feel satiated after a meal, nor do they promote foraging (Vieuille-Thomas et al., 1995). When straw, a substrate that promotes foraging, was provided, the sows spent significantly less time manipulating chains and bars, sham chewing and tongue sucking and spent significantly more time manipulating the straw (Whittaker et al., 1997, 1999). Thus, stereotypies in group-housed sows can be reduced or eliminated much more readily than in stall or tether housed sows.

In stalls, the amount of space provided per sow is of concern, as the stalls are often too narrow in proportion to the width of the sows. The length and breadth of a sow can affect posture changes. A shorter and narrower sow is capable of making more frequent and rapid posture changes than a larger sow housed in the same sized stall (Hansen and Vestergaard, 1984; Taylor et al., 1988; Anil et al., 2002a; Boyle et al., 2002). According to Curtis et al. (1989), when assessing the dynamic space requirements of sows, stalls need to be much wider to accommodate lying and turning. Hence, the welfare of sows in stalls could be improved if more space was provided per sow.

The design of the stall is also important. Sows housed in stalls with horizontal bars had fewer and shorter aggressive interactions than sows housed in stalls with vertical bars (Barnett et al., 1991). Sows housed in stalls with horizontal bars had shorter and fewer aggressive encounters but these sows had higher cortisol levels. A lower level of aggression was seen in sows housed in stalls with horizontal bars because the sows actively avoided head to head contact with neighboring sows. The observable aggression was did not influence the stress levels, the reason for the elevated cortisol in sow housed in stalls with horizontal bars is likely associated with the avoidance of neighboring pigs, which results in unsettled dominance relationships.

Several modifications have been made to stalls in an effort to improve sow welfare. One study examined stalls that enable gilts to turn around within the stall safely by modifying the stall to flare out at one end. The stall was also lengthened to increase movement and promote exercise (McFarlane et al., 1988). The sows made on average 11 turns per day within the modified stalls. The turns were not associated with the attainment of food or water, rather the sows were turning to satisfy the motivation to turn around (McFarlane et al., 1988). In another study, in stalls with hinged pivoting sides, the sows made 15.8 to 23.6 turns per day, depending on whether one or both sides of the stall pivoted (Johnson et al., 1990). Bergeron et al. (1996) studied the behaviour of gilts housed in stalls in which both sides pivoted (turn around stalls). Gilts in the turn around stalls made an average of 75 turns per day. The higher rate of turns made by the gilts in the study by Bergeron et al. (1996) was likely due to the gilts being much smaller than the sows used in previous experiments. Gilts housed in the turn around stalls had lower plasma cortisol concentration than those housed in conventional stalls (Bergergon et al., 1996).

In terms of movement within the stall, McFarlane et al. (1988) found that regardless of length and design of the stall, sows moved on average 130 m/d, which is significantly less than the 200 m/d recorded in group housed sows (the feeder, lying and dunging areas were all within very close proximity). Stall-housed sows are not exercising as much as group housed sows and the difference likely due to the type of

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movements a sow is capable of making in a stall. These studies demonstrated that sows have a desire to turn around and to move within their environment. Unfortunately, the modified stall never became popular due to sanitation issues, even though they improved the welfare of sows.

2.2.2. Group Housing

With tethers and stalls quickly becoming socially unacceptable methods of housing sows, globally, the pork industry has begun evaluating various types of group housing systems. Housing sows in groups is not entirely free from welfare issues, but the issues are dependent on the type of system. In addition, the welfare issues that arise with group housing tend to be ones that can be solved by altering the management techniques employed. While, the issues associated with stalls and tethers are due to the system, and management cannot solve these problems (Appleby, 2005). Aggression is an example of how management and the type of group housing system used can affect the welfare of sows (Edwards et al., 1999). Other concerns associated with group housing are the lack of control over individual feed intake, social facilitation of feeding, queuing at the feeder, injuries, social stress and potential losses in productivity. Although there are welfare concerns associated with group housing, the advantages such as freedom of movement, the ability to express normal behaviours, better thermoregulation and social contact, are increasingly being seen to outweigh the disadvantages.

2.2.2.1. Floor Feeding

In a floor feeding system, the daily feed allowance for all the sows is spread out on the floor. Feeding sows in this manner creates a highly competitive feeding environment, and results in high levels of aggression (Edwards, 1992). Aggression levels become negligible once all the feed is consumed (Csermely and Wood-Gush, 1987b).

Another concern with floor feeding sows is the inability to control the individual feed intake. Dominant sows have been found to spend more time feeding than subordinate sows (Martin and Edwards, 1994) and concentrate on defending their portion of the feed pile (Csermely and Wood-Gush, 1987b; Edwards, 1992). Csermely (1989) found that dominant sows instigated more aggressive encounters and frequently interrupted their meal to attack a neighboring sow.

Dominant sows eat at the center of the pile, while the subordinates tend to feed at the edges of the pile (Csermely and Wood-Gush, 1987a; Csermely, 1989). Subordinate sows typically do not gain access to the center of the pile until the dominant sows have finished eating, and by this time the majority of the feed is gone (Csermely, 1989). According to Edwards et al. (1993), lower ranking sows are deprived of an adequate amount of food when they are floor fed, which results in these sows having lower weight gains (Brouns and Edwards, 1994; Martin and Edwards, 1994).

Housing similar sized sows with comparable feed requirements together can minimize the problem of unequal feed distribution within a group, as this reduces the competitive advantage of certain sows (Gonyou, 2005). Providing adequate space and distributing the feed over a wide area can also allow for a more even feed distribution (Gonyou, 2005).

2.2.2.2. Partial or Full Feeding Stalls

Providing barrier between spaces at the feeding trough has been used to prevent the dominant sows from monopolizing the feed and to minimize aggression. The length of the barrier ranges from shoulder length partitions to full-length stalls (Brouns and Edwards, 1992. If partitions are not provided at the feeder, aggression and displacements are problematic (Andersen and Bøe, 1982).

 Some producers share the feeding stalls with several groups instead of having a stall for each sow in every group. This results in more efficient use of the space, allows the stockperson to health check while moving the animals, and pregnancy checking, treatment administration and breeding can be carried out while the sows are locked within the feeding stall (Gonyou, 2005).

The inclusion of partial stalls at the feeder was successful at reducing aggression during feeding (Barnett et al. 1993a, 1996). The length of the partitions provided in a feeding stall system can affect the level of aggression. As the partition length increased, the number of aggressive encounters and displacements at the feeder was reduced (Andersen and Bøe, 1982; Andersen et al., 1999).

Some disadvantages arise with using a partial stall-feeding system. Space is typically restricted in this housing system because the stalls take up extra space that could be available to the sows. The decreased space available also negatively affects aggression levels at mixing. The sows are more aggressive, at mixing, because there is not enough space available for them to display submissive behaviours or retreat from an aggressive encounter (Brouns and Edwards, 1992). Another disadvantage with this feeding system is that producers are unable to dispense the feed to meet each sow's feeding requirements (Brouns and Edwards, 1992). If the sows are locked into the stall, the producer can give extra feed to sows that need it (Gonyou, 2005). Andersen and Bøe (1982) also found that unless the sows were locked into the stalls, having partitions at the feeder increased the amount of vulva biting within the pen.

2.2.2.3. Trickle Feeding or Bio-Fix System

In a Biofix system, sows are still fed as a group with dividing partitions at the trough. However, the feed is dispensed in small quantities at regular intervals. The intermittent delivery of small feed portions prevents the accumulation of excess feed in the trough; therefore, it is no longer beneficial for sows to displace others. The challenge with this system is determining the correct rate at which to dispense the feed. It must be fast enough to prevent the fast eating sows from losing interest, but slow enough to allow the younger, slower sows enough time to eat to prevent feed from accumulating (Brouns and Edwards, 1992).

This system also minimizes aggression during feeding and allows for uniform feed distribution. However, it does not allow for individual rationing (Brouns and Edwards, 1992). In the Bio-fix and partial stall feeding systems, the producer can group sows with similar nutritional requirements in the same pen to more accurately meet the sows' nutritional needs (Gonyou, 2005).

2.2.2.4 Electronic Sow Feeding System

Another type of group housing is an Electronic Sow Feeding system. A transponder attached to the sow's ear, allows for individual identification by the feeder's sensors, which makes it possible to feed each sow based on her specific nutritional requirements.

One Electronic Sow Feeding station has the capability of feeding 55 to 60 sows within a 24-hour cycle (Gonyou, 2005). Electronic Sow Feeding stations that combine the entrance and exit are becoming obsolete because they are known to lead to vulva biting (Edwards and Riley, 1986). It is more common for the sows to enter at the back of the feeder and exit at the front. While within the Electronic Sow Feeding station, the sows are able to consume their meal undisturbed, representing another advantage of the system.

There are some disadvantages to using an Electronic Sow Feeding system. This system only permits one sow to eat at a time, which can create a highly competitive feeding environment amongst the sows (Olsson et al., 1992; Jensen et al., 1995). The thwarted motivation to feed, caused by an occupied feeder, may cause stress (Durrell et al., 2002). This system forces some sows, especially the subordinate sows, to change their diurnal rhythm because they must eat later on at night (Edwards, 1992).

Queuing at the feeder entrance is a problem unique to the Electronic Sow Feeding System. Queuing is considered problematic because it is related to aggression. The number of aggressive encounters at the feeder was positively correlated with the percentage of time sows spent queuing (Anil, 2004; Anil et al., 2005b).

During the two-hour period before the feeder is reset, there is a large increase in the frequency of visits made to the Electronic Sow Feeding station (Knowles et al., 1989). The sows make those visits prior to the feeder being reset because they have learnt to anticipate the next feeder reset (Edwards et al., 1988).

Queuing is most problematic during the first hour of the feeding cycle (Knowles et al., 1989; Weber et al., 1993). During the first three hours following the feeder reset, 30% of the 37 sows in the group were found to be within 5 m of the Electronic Sow Feeding station. During the next three hours, the number of sows found within the same area dropped to 21%. Throughout the remainder of the feeding cycle, 19% of the sows within the group were within 5m of the Electronic Sow Feeding station (Smith, 1986).

Queuing is common amongst sows that are waiting to get into the Electronic Sow Feeding station. However, sows that have finished their daily meal also return to the entrance repeatedly. During the latter part of the feeding cycle, when the subordinate sows typically eat, the dominant sows will return to the Electronic Sow Feeding station and attempt to reenter (Hunter et al., 1988; Tanida et al., 1993; Weber et al., 1993). Beckett et al. (1986) found that during a 24h feeding cycle, a group of 25 sows made, on average, 239 to 343 visits to the Electronic Sow Feeding station entrance. Out of those visits, only approximately 7% resulted in a sow entering the feeder. The extra visits are made to the Electronic Sow Feeding station because some sows learn how to cheat the gate and steal portions of another sow's meal (Beckett et al., 1986; Edwards et al., 1988). Low-ranking sows tend to eat slower, so they typically still have food remaining in the trough when the gate opens to let the next sow in. This allows other sows to enter the Electronic Sow Feeding station and steal the remainder of the low-ranking sows feed, especially if the system does not prevent sows that have already eaten from entering the feeder (Tanida et al., 1993). Not only does this prevent sows from consuming their daily feed allowance in its entirety, but the sows gathering at entrance and exit of the feeder make it extremely difficult for a sow to leave the feeder once she has finished eating (Lehman, 1990).

To prevent sows from cheating, modifications have been made to the entrances of Electronic Sow Feeding System stations. In the newer model used in this study (Insentec, B. N., Marknesse), the rear gate locks out sows once they have finished their

daily feed allotment. Thus, sows cannot enter the Electronic Sow Feeding station until the feeder resets. Another modification made to the station, is that there is a second sensor located in the trough. For food to be dispensed, a sow must place her head within the trough. Cheating is discouraged because feed is not available to a sow that has snuck in behind another sow. The first sow will not have been able to place her head in the trough, thus there is not any food available to the sow that cheated the gate.

The extent to which sows queue at the Electronic Sow Feeding station is affected by the time of day when the daily feeder resets occurs. By starting a new feeding cycle in the evening, Jensen et al. (2000) was able to reduce queuing and aggression levels. Nielsen et al. (2000) was able to reduce aggressive encounters by 15% by moving the feeder reset from 16:00 to 22:00 h.

There are other ways to reduce the number of unnecessary visits to the Electronic Sow Feeding station. Locating the feed station away from where the sows rest (Edwards et al., 1988) and limiting the amount of time during a 24h period that sows can enter the feeder (Lehman, 1990) can prevent sows from congregating around the entrances and exits. However, sows prefer having several small meals throughout the day. Thereby, limiting access to the Electronic Sow Feeding station could cause frustration because the sows are unable to express their individual feeding preferences (Eddison and Roberts, 1995). Sows were observed to queue less frequently and for a shorter amount of time when the number of feeding cycles was reduced from two to one per day (Weber et al., 1993).

2.2.2.4. Hurnik-Morris System

To reduce competition at the feeder entrance, the Hurnik-Morris system was developed. In this system, sows are housed in small groups and several groups share the same Electronic Sow Feeding stations. There are enough feeders available for every sow in the group to eat at the same time. Three times per day, an electronic gate opens and allows the sows access to the feeders. Since all the sows within the group can eat at once, it eliminates the aggression that results from the sows competing to enter the feeder (Morris and Hurnik, 1990). Sows that do not exit the feeder once the designated

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amount of time to eat has elapsed receive mild electric shocks. The sows are allowed 10 minutes to walk in the alleyway immediately after eating. To assist with heat detection, the sows are given fence line contact with a boar while they are in the alleyway. A sensor located at the boar pen records the sow's identification by reading her transponder if she has extended contact with the boar (Morris and Hurnik, 1990). After 10 minutes of exercise, an electronic gate moves the sows back to the pen.

The benefits of this housing system are that it reduces competition at the feeder, allows the sows to socialize and exercise, promotes socially facilitated feed consumption and having the more complex environment helps to reduce boredom within the group (Morris and Hurnik, 1990; Olthoff et al., 1990; von Borell et al., 1992). This system allows for individual rationing (Morris and Hurnik, 1990; Brouns and Edwards, 1992). Queuing at the feeder entrance is also eliminated because the sows do not have constant access to the feeders.

Aggression still occurs immediately after mixing, and immediately before feeding in the Hurnik-Morris system (Morris et al., 1993). Competition for the feeders is not apparent, but the use of particular feeders is influenced by social factors, such as dominance (Morris et al., 1993). There are other disadvantages associated with the Hurnik-Morris system. This system does not allow sows the freedom to eat when they are hungry and generates frequent excitement within the group, as the sows anticipate the three daily feedings (Morris et al., 1993).

Vulva biting was not observed (Morris et al., 1993) and in a later study; there was not a difference in the lameness or injury scores between sows in stalls and in the Hurnik-Morris system (Morris et al., 1997). Thus, the Hurnik-Morris system is effective at reducing some of the problems that could influence the welfare of sows, but this system does not eliminate all the problems associated with group housing. When Bracke (2001) tested the welfare assessment model designed for gestating sows, the Hurnik-Morris system was the highest ranked indoor group housing system, but the outdoor group housing systems were considered more welfare friendly.

2.2.2.5. Outdoor or Paddock System

There is the option to group house sows outdoors. Small huts that contain straw for bedding provide shelter for the sows during inclement weather. The total daily feed allotment is distributed over the ground.

An advantage to housing sows outdoor in paddocks is the increased amount of space typically provided, which results in lower aggression levels compared with indoor loose housing systems (Jensen and Wood-Gush, 1984). Housing sows outdoors also provides a more enriched environment, but leaves the sows vulnerable to extreme weather patterns (Brouns and Edwards, 1992). Other issues unique to outdoor housing are increased problems with disease control due to the inability to control vectors such as birds and mice (Brouns and Edwards, 1992). The inability to disinfect the soil may promote disease, but rotating the sows through different pastures throughout the year minimizes the build up of pathogens within the soil.

2.3. Aggression

One of the main arguments in favor of the continued use of gestation stalls is the lower level of aggression in stall housed sows (Carter and English, 1983; Barnett et al., 1988). There is a difference in the manner in which aggression manifests itself in group and in stall housing systems. Group housed sows display aggressive behaviours such as parallel pressing, levering and withdrawing, while stall housed sow make unusual back and forth movements (Dolf, 1986; Barnett et al., 1988). Interestingly, the performance of the unusual behaviours by stall housed sows persisted longer than the duration of aggression seen immediately after mixing group housed sows (Dolf, 1986).

Studies have found that aggression levels can be higher in stall or tether housed sows (Jensen, 1982, 1984; Vestergaard and Hansen, 1984; Barnett et al., 1987, 2001; Friend et al., 1988). Approximately 90% of the social interactions between stall-housed sows are aggressive in nature and the necessary submissive behaviours are rarely displayed (Jensen, 1984). Arellano et al. (1992) found that group housed sows displayed more submissive behaviours, while stall housed sows displayed aggressive behaviour

more frequently. Sows housed in stalls also have difficulty ending an agonistic encounter, and the winner of the encounter is not always apparent (Mendl et al., 1993). The aggression in tethered sows is the same. Barnett et al. (1988) found that when tethered sows were threatened, they were more likely to retaliate than withdraw. Tethered sows also bit neighboring sows more than sows kept in groups (Barnett et al., 1984a).

The amount of time that a sow has been housed in either a stall or group affects aggression levels (Mendl et al., 1993). Gilts housed in stalls were involved in fewer aggressive encounters than gilts kept in either a feeding stall or an Electronic Sow Feeding system. However, by the third parity, aggression levels in stall and both group-housing systems were similar.

The duration of aggression that occurs upon introduction of sows to stalls or group housing varies. Aggression levels of stall housed sows were elevated during the first three days of being housed in stalls, whereas aggression levels in a feeding stall system were only elevated for twenty-four hours post-mixing (Dolf, 1986). The extended duration of aggression in stall-housed sows was likely because the stalls do not allow the sows to display the behaviours indicative of the end of an aggressive encounter. The high rate of stereotypies performed in stall-housed sows may be due to the large number of unresolved conflicts between neighboring sows (Broom et al., 1995).

Dominance can affect the level of aggression within a group. In an Electronic Sow Feeding system, the dominant sows instigate more aggressive encounters (Mendl et al., 1992). Not surprising, the dominant sows also win more aggressive encounters than subordinate sows (Martin and Edwards, 1994). During the first 30-minutes after regrouping, the dominant sows were involved in more agnostic interactions than subordinate sows (Otten et al., 1997). The same pattern was seen in nursery pigs at mixing. The pig that was involved in the most vigorous fighting 30 minutes following mixing, tended to be the most dominant member in the group, once the hierarchy was established (Meese and Ewbank, 1973).

The research available on the effectiveness of reducing aggression by providing bedding is quite variable. Some studies have found that the provision of straw reduced aggression levels in Electronic Sow Feeding (Krause et al., 1997) and feeding stall systems (Andersen and Bøe, 1999). Durrell et al. (1997) examined aggressive interactions in a feeding stall system, in which the sows were housed in a barren environment or were provided spent mushroom compost for bedding. The provision of spent mushroom compost slightly reduced aggression the day of mixing. However, there was not a significant difference in the level of aggression between the two treatments after mixing (Durrell et al., 1997). Sows with bedding spent more time lying the day of mixing, which may be why there was less aggression. The higher aggression levels seen in sows housed in a barren environment were reflected in the increase in injuries (Durrell et al., 1997).

Other studies have found that providing bedding in a floor feeding system actually resulted in higher levels of aggression (Whittaker et al., 1998, 1999). The higher aggression levels were attributed to the increased activity level of sows provided straw, because it increased the chances of sows encountering one another (Whittaker et al., 1999).

Regardless of whether bedding substrates are effective at minimizing aggression, there are other advantages associated with providing sows with straw, in that it provides a softer floor surface and improves traction. Andersen and Bøe (1999) detected more movement disorders in sows that were housed on concrete floors, and the higher level of movement difficulties was associated with a higher return to estrus rate. Straw insulates the sows, which may lower their maintenance energy requirements (Marchant et al., 1997; Spoodler et al., 1997). It is also a substrate that the sows can root and chew and it may fill the gut causing the sows to feel satiated (Edwards, 1998; Jensen et al., 2000). Thus, even though the straw can become a resource that the sows fight over, the benefits straw provides in terms of improving comfort and satisfying feeding motivations may outweigh the potential increase in aggression.

2.3.1. Aggression Post-Mixing

When sows first enter group housing, the aggression that occurs generates a tremendous amount of concern in terms of welfare. In a group housing system, the highest level of aggression occurs during the week immediately following mixing (Durrell et al., 2002; O'Connell et al., 2004). Karlen (2005) compared the aggression levels the week of mixing to the levels 9 weeks post-mixing, in a large group feeding stall system. There was a significant decrease in aggression by week 9 compared with aggression levels at mixing. At the time of mixing, the majority of interactions among the sows were vigorous fights, but by 9 weeks after mixing, the interactions were head knocks, single bites and threats (Karlen, 2005).

Bornett et al. (2000) found that the highest number of aggressive encounters occurred the day of mixing in group housing systems. The most severe levels of aggression were seen during the first hours immediately after mixing (Luescher et al., 1990; Barnett et al., 1993a; Marchant et al., 1995; Spoolder et al., 1997 Kay et al., 1999; Durrell et al., 2002; O'Connell et al., 2004;). Kay et al. (1999) noted that in a feeding stall system, one third of all the aggression that occurred within the first two days of mixing took place during the first two hours immediately after mixing. When D'Eath (2002) mixed weanling pigs, aggression was most prevalent during the 30-minute period immediately after mixing. The high levels of aggression at mixing were reflected in the elevated number of skin lesion in the days following mixing (Jensen et al., 1995; Durrell et al., 2002).

Mount and Seabrook (1993) examined the aggression at mixing in a feeding stall system. The aggression levels were high and very intense during the first 10 minutes after mixing. However, 20 minutes after mixing, the number of attacks and total number of aggressive encounters began to decline.

The type of management within group housing can also affect aggression levels. Sows housed in a dynamic housing system are involved in more aggression because the interval between regroupings is short. Every time a new group of sows is introduced into a dynamic pen, aggression levels temporarily increase (den Hartog et al., 1993; Durrell et al., 2002). On the day of mixing, the aggression levels of resident sows, housed in an

Electronic Sow Feeding system, were 15% higher than the levels recorded the previous day (Lambert et al., 1986). However, Spoodler et al. (1997) did not find a significant difference in the levels of aggression on mixing and non-mixing days in a dynamic Electronic Sow Feeding system. The aggression at mixing in a dynamic pen tends to be initiated by the resident sows, but is directed towards the newly introduced sows. However, in a feeding stall system, there is still some aggression amongst the resident sows (Mount and Seabrook, 1993). During the first three hours post mixing, 87% of the fights were between new and resident sows (Moore et al., 1993).

How a dynamic pen is managed can affect aggression levels within the pen. The number of times sows are regrouped during their gestation cycle does not affect aggression levels (Jensen et al., 2000). The differences in aggression levels were compared when 10, 20, 30 or 40% of resident sows were replaced with new sows. The percentage of resident sows replaced did not affect the overall aggression levels. However, introducing a higher proportion of new sows resulted in higher aggression levels amongst the newly introduced sows (O'Connell et al., 2004). When a smaller percentage of the group was replaced, the new sows spent less time resting in the kennel area and if the sows did lie in the kennel area, they spent very little time in contact with resident sows. If 20% or more of the resident group was replaced, the proportion of new to old sows made it possible for the new sows to take over one particular kennel area (O'Connell et al., 2004).

When the group size is kept constant, the amount of space provided can influence aggression. Olsson and Samuelsson (1993) reduced aggression levels at mixing by 10% when the space allowance increased to 6.5 m^2 per sow, from 3.0 m^2 per sow in a feeding stall system. When sows were floor fed, Barnett et al. (1993b) was not able to reduce aggression at mixing by increasing the space allowance to 3.4 m^2 per sow from 1.4 m^2 per sow. To effectively reduce aggression by providing increased space per sow, there needs to be enough space within the pen for the sows to display the necessary submissive behaviours.

A variety of methods to reduce aggression at mixing have been examined. Unfortunately, most methods have proven to be unsuccessful at reducing aggression. According to Mendl (1995), the methods used to reduce aggression at mixing tend to focus on the symptom, the aggression, rather than finding a solution based on the cause.

Masking olfactory inputs, by spraying the pig with Nilodor, Eucalyptus oil (Barnett et al., 1993a) or camphor (Luescher et al., 1987) was not effective at reducing aggression at mixing. The excitement generated by the application of the camphor odor agent caused aggression levels to exceed those seen in the control sows (Luescher et al., 1990).

Partial stalls have often been included in the pen to enable sows to display submissive behaviours and protect themselves from aggressive advances. However, the inclusion of partial stalls in the pen did not reduce aggression levels at mixing (Luescher et al., 1987; Barnett et al., 1993b, 1996). During the first 90 minutes post-mixing, sows with stalls in the pen fought less but the stalls were not effective in reducing skin lesions (Barnett et al., 1992).

Researchers thought that sedating the sows at the time of mixing would reduce the overall aggression levels, as the sows would be incapable of fighting. The two most commonly investigated sedatives are amperozide and azaperone (or Stresnil®). Amperozide was successful at reducing aggression that occurred during the first 60-minutes after mixing. However, 90-minutes after mixing, the plasma cortisol concentration of sows given amperozide was significantly higher than the control group (Barnett et al., 1993a, 1996). In 12-week-old pigs, the administration of amperozide before mixing eliminated the fighting that took place at mixing and there was less damage to the integument (Björk et al., 1988). In another study involving young pigs, Gonyou et al. (1988) found that azaperone treated pigs fought less than the controls.

In a study examining aggression in grow-finish pigs, the aggression that took place during the first two hours after mixing was eliminated when azaperone was administered (Symoens and van der Brande, 1969). When the sedative wore off, the pigs fought at a level equivalent to levels in control groups at that same time. While the pigs were sedated, they had become accustomed to one another via sensory cues such as sight and smell (Symoens and van der Brande, 1969).

Other studies have found that these sedatives are not effective in reducing aggression. Immediately after mixing, sows that were given the sedative azaperone had similar aggression levels as sows not given a sedative. (Csermely and Wood-Gush, 1987a; Luescher et al., 1987). Luescher et al. (1990) found that azaperone only delayed the fighting by 2 to 4 hours. In grow-finish pigs, the administration of azaperone delayed the aggression and postponed the stabilization of the dominance hierarchy for three weeks (Tan and Shackleton, 1990). In weaned pigs, once the azaperone wore off, the aggression levels were equivalent to the levels seen in control animals the first hour after mixing (Blackshaw, 1981). Another draw back to using amperozide is that it induced vomiting in some of the sows (Barnett et al., 1996) and young pigs (Björk et al., 1988; Gonyou et al., 1988).

There have been some successful ways of reducing aggression at mixing. The time of day that the sows are mixed was examined. Sows have a diurnal activity pattern, thus mixing sows when the sows are less active, after the afternoon peak of activity, should reduce aggression levels. Csermely and Wood-Gush (1987a) compared aggression levels of sows mixed in the morning with sows mixed late in the afternoon. Sows that were mixed late in the afternoon were involved in fewer agonistic interactions. Mixing sows after dark reduced aggression levels 15 to 90 minutes post-mixing, but it was not effective at reducing aggression during the 15-minute period immediately after mixing (Barnett et al., 1994, 1996).

Studies have attempted to distract sows from fighting at mixing by depriving them of feed before mixing. The presence of feed at mixing should lower aggression levels because the motivation to eat should be much stronger than the desire to fight. The presence of feed on an *ad libitum* basis was not successful at reducing aggression at mixing. The aggression levels in sows with feed withheld prior to mixing were equivalent to the aggression levels in the control sows (Luescher et al., 1987; Barnett et al., 1994). Depriving sows of feed until mixing creates extra excitement within the group and causes high levels of aggression amongst the sows (Luescher et al., 1990).

Docksey et al. (1998) compared the aggression levels of sows, in an Electronic Sow Feeding system, that were restricted fed or had *ad libitum* access to a high fibre diet. The sows with *ad libitum* access to feed spent more time fighting because it created more demand for the Electronic Sow Feeding station

However, if the sows did not fast before mixing, the provision of feed on an *ad libitum* basis at mixing actually reduced the number of aggressive interactions up to 24 hours post mixing in a partial feeding stall system (Edwards et al. 1994). The presence of feed on an *ad libitum* basis resulted in the sows having fewer injuries 48 hours post-mixing.

The impact on aggression that the inclusion of a boar in the pen with sows at mixing was investigated. An early study by Luescher et al. (1987) found that the presence of a boar with gilts at mixing was not effective at reducing aggression. Later studies have shown that the presence of a boar within a group of sows at mixing was effective at reducing aggression (Leuscher et al., 1990; Barnett et al., 1993a; Séguin et al., 2005). Séguin et al. (2004) found that housing a boar with sows at mixing also decreased the number of scratches they received the day after mixing. There is the potential risk of injury resulting from sexual behaviours if a boar is housed in the pen with the sows (Barnett et al., 1993a).

Why the inclusion of a boar with sows at mixing was effective at reducing aggression is unknown. There are several theories such as the secretion of pheromones, the boar being the biggest and most dominant animal within the pen, or the performance of sexual behaviours (Barnett et al., 1993a).

Work by van Putten and Buré (1997) suggested aggression could be reduced if gilts were repeatedly mixed throughout development. The repeated mixings should teach the gilts how to recognize threats, efficiently fight, to know when to quit fighting and when not to fight at all. All gilts studied were mixed twice, but the experimental gilts underwent two, three or four additional mixings. At five months of age, in an arena test, gilts that were mixed three or four additional times during development fought significantly less than control gilts. Significantly fewer attacks were made by gilts that were mixed three or four times, because they were effectively able to use threats (van Putten and Buré, 1997).

Therefore, as sows gain experience with being mixed into group housing in each subsequent gestation cycle, they should become less aggressive as they learn how to estimate their opponent's abilities. Broom et al. (1995) found that as sows became increasingly familiar with the process of regrouping, the amount of aggression at regrouping decreased. Minimal levels of aggression were seen when sows were regrouped into an Electronic Sow Feeding System for the fourth time. It is likely that the younger sows within a group cause the high levels of aggression seen at mixing due to lack of experience with aggressive encounters.

There are ways to manipulate the sows' environment and various management techniques used to reduce the amount of aggression at mixing. With that being said, there will always be a certain level of aggression that cannot be eliminated, as aggression is necessary for the development of the stable dominance hierarchy within the group (Luescher et al., 1987, 1990). Therefore, what needs to be determined is what impact the aggression at mixing has on the sows' welfare, and whether or not it is as significant as the impairments brought on by housing sows in stalls.

2.3.2. Aggression at the Feeder

Once dominance has been established, aggression in group-housed sows occurs primarily at feeding. This aggression is disconcerting because it can be a daily occurrence (Lambert et al., 1983; Csermely and Wood-Gush, 1987b; Marchant et al., 1995; Andersen et al., 1999; Jensen et al., 2000). Csermely and Wood-Gush (1987a) found that aggression levels were quite low when the sows were not feeding. Less than 10% of the daily aggression takes place outside of the daily feeding periods in nursery pigs (Meese and Ewbank, 1973).

Aggression at the feeder is most prominent in competitive feeding environments, like the ones created in floor-feeding and Electronic Sow Feeding systems (Hodgkiss et al., 1998). Lambert et al. (1986) noted that 58% of the aggressive encounters involved the actual Electronic Sow Feeding station. Nielsen et al. (2000) found that 90% of the aggressive encounters in an Electronic Sow Feeding System occurred at the entrance to the feeder. The number of aggressive encounters at an Electronic Sow Feeding station

entrance was low before the start of the feeding cycle. However, the aggression levels increased immediately after the cycle began (Weber et al., 1993). Agonistic interactions were more frequent and skin lesions were more severe in sows fed via an Electronic Sow Feeding station compared with sows fed in feeding stalls (Durell et al., 2002).

The number of feedings per day in an Electronic Sow Feeding system affects the aggression levels. Demand for access to the Electronic Sow Feeding station increases as the number of feedings per day increases. The increased demand results in increased aggression because the sows compete for access to the Electronic Sow Feeding station more frequently (Lambert et al., 1985; Olsson et al., 1992). Weber et al. (1993) reduced aggression levels by 50% in an Electronic Sow Feeding system, by switching from two to one feeding cycle per day. The Hurnik-Morris system was designed to reduce competition at the feeder. However, there was still an obvious increase in aggression prior to the three daily feedings (Morris et al., 1993).

Aggression at feeding could be reduced if the feed was available on an *ad libitum* basis. This is typically not a viable option, because it does not provide control over the sow's growth (Barnett et al., 1994). Sows that were given *ad libitum* access to feed, ate three times the amount that was provided to sows with restricted feed intake (Petherick and Blackshaw, 1989). Overweight sows can lead to productivity problems, so rather than solving the problem of aggression at feeding, you switch from one production problem to another. However, Edwards et al. (1993) found that allowing sows *ad libitum* access to a feedstuff high in fiber resulted in higher average daily weight gains and increased backfat thickness, yet obesity was not a problem.

Bressers et al. (1993) examined the effects of providing corn silage on the floor, 30 minute before the Electronic Sow Feeder reset, and again later in the afternoon. This reflected the diurnal feeding pattern typically seen in feral populations. Feeding corn silage was effective at reducing competition for the Electronic Sow Feeding station (Bressers et al., 1993), aggression at the station (Jensen et al., 2000) and vulva biting (van Putten and van de Burgwal, 1990). Thus, providing another food resource in abundance can reduce the demand for access to the Electronic Sow Feeding station, which reduces aggression and the negative consequences associated with it.

A study by Weng et al. (1995) compared the aggression levels in a feeding stall system. Stable groups of six sows were housed at various stocking densities midway through gestation. The highest levels of aggression occurred at a space allowance of 2.0 m^2. Fewer sows would retreat when attacked at a space allowance of 2.0 m^2 per sow. The lowest aggression levels were seen at a space allowance of 4.8 m^2 per sow.

Lesions due to aggression are affected by the amount of space provided; increasing the space provided to the sows reduced the lesions (deKoning, 1983). The highest injury scores and aggression levels were recorded for sows housed at a space allowance of 2.0 m^2 per sow. Increasing the space allowance from 2.0 m^2 to 2.4 m^2 per sow and 2.4 up to 3.6 m^2 per sow significantly decreased the total number of lesions received by a sow (Weng et al., 1998). For a more welfare friendly system, a minimum of 2.4 m^2 per sow was needed (Weng et al., 1998). Thus, by providing abundant space and feed resources, aggression at feeding can be minimized. If the sows are not forced to compete for access to the feeder or feed, aggression is not as severe at the daily feedings.

2.4. Injuries

A common method of assessing the welfare of pigs is to investigate the extent of their injuries. According to deKoning (1993), the skin lesions can reflect a change in a sow's behaviour patterns, measure health status, and thus the welfare of the animal. However, when comparing different sow gestation housing systems, especially stalls versus group housing, the effectiveness of this measurement is questionable because the etiology of skin lesions varies within each housing system. In terms of damage to the integument, group housed sows sustain damage when they interact with other sows, while stall housed sows receive lesions while lying (Edwards, 1992; Gjein and Larssen, 1995a). Group housed sows sustained more scratches and stall housed sows sustained more abrasions (Karlen, 2005). The presence of callosites, alopecia and leg swellings are more common in stall housed sows, and reflect long-term exposure to pressure against hard surfaces (Jensen et al., 1995).

The location of the damage is also based on the type of housing. The majority of injuries sustained by sows housed in stalls are on the head and limbs (Anil et al., 2002b). Group housed sows tend to injure their ears, head, neck, shoulders and flanks, and these injuries are a direct result of aggressive encounters (McGlone, 1985; Luescher et al., 1990; Gjein and Larssen, 1995a; Hodgkiss et al., 1998; Anil et al., 2004). When aggression levels in group housing are low, the regions of the body that are commonly damaged during aggressive encounters receive minimal damage. Instead, the injuries are concentrated on the flanks, shoulders and hindquarters, which occur when sows move through the lying area to the feeder (Hodgkiss et al., 1998).

Another concern associated with group housing is the increased probability of incurring damage to the vulva (den Hartog et al., 1993; Gjein and Larssen, 1995a). Damage to the vulva is typically a result of aggression (Rizvi et al. 2000). The occurrence of vulva biting is related to the stage of pregnancy, with damage more likely late in gestation because the vulva becomes swollen (Tanida et al., 1993; Anil et al, 2004). Anil et al. (2004) found that in an Electronic Sow Feeding system, the injury scores decreased on days 28 and 56 of gestation, but rose near the end of gestation because damage to the vulva and udder increased.

Lameness is another problem commonly associated with group housing. Loose housed sows were culled more frequently for mobility problems than stall housed sows (Gjein and Larssen, 1995a). However, lameness may be more prevalent in group-housed sows because it is much easier to detect when the sows move around the pen (Karlen, 2005). Karlen (2005) found that stall housed sows had more severe locomotion problems than group housed sows and stall housed sows had a higher culling rate due to lameness.

The amount of time that has passed since the sows were first mixed can affect the number of skin lesions present on group-housed sows. Lesions on group housed sows are most prevalent immediately after mixing (Gjein and Larssen, 1995a; Burfoot et al., 1997; Arey and Jamieson, 1998; Grigoriadis et al., 2000; Anil et al., 2004). Arey (1999) determined that the lesion scores of group housed sows peaked three days post-mixing and remained elevated until 7 days post-mixing, at which time, they began to decrease. The high levels of injuries that occur immediately after mixing are a result of the reestablishment of the dominance hierarchy (Anil et al., 2004). The plateau in the injury

scores one week post-mixing indicates that the dominance hierarchy has been established (Arey, 1999).

The extent of injuries and vulva biting is affected by the type of group housing system. The highest lesion scores are typically recorded for sows that have been housed in Bio-fix and Electronic Sow Feeding systems. Electronic Sow Feeding systems are also associated with high rates of vulva biting, because of the highly competitive environment at the feeder. The lowest injury scores are seen in the feeding stall system, which does not differ significantly from the scores of the stall housed sows (Vermeer et al., 1999; Backus et al., 2001). Floor feeding also results in the sows having very high injury scores.

How the Electronic Sow Feeding system is managed can also affect the severity of damage to the vulva. Damage to the vulva can be reduced if other sows are prevented from entering the feeder while another sow is consuming her meal (Jensen et al., 1995). Typically, when a separate entrance and exit is provided, vulva biting is not as critical. However, Krause et al. (1997) found that there were more injuries sustained to the hindquarters of sows that were housed in Electronic Sow Feeding Systems, with a separate entrance and exit.

The number of times the sows are fed per day can affect the degree of injury to the vulva. Feeding sows twice a day, in an Electronic Sow Feeding system, reduced the chance of vulva biting by three-fold when compared with sows that were fed once per day (Rizvi et al., 1998). However, increasing the number of feedings also resulted in higher levels of aggression in a study by Weber et al. (1993). Thus, how the Electronic Sow Feeding system is designed and managed may dictate how problematic vulva biting and aggression will be.

Vulva biting does not only occur in an Electronic Sow Feeding system. Feeding sows in stalls was not effective at reducing vulva biting, in a study by Rizvi et al. (1998). In a feeding stall system, there was an increase in the prevalence of vulva biting in groups that had full stalls compared with those groups without partitions or with shoulder length partitions (Andersen et al., 1999). However, the benefits associated with feeding stalls, such as less aggression at feeding and more even feed intake, outweigh the possibility of vulva biting. In addition, if the Bio-fix feeding system were in place,

vulva biting would likely not be an issue because the vulva is typically bitten when a sow attempts to displace another (Rizvi et al., 1998). Vulva biting in feeding stall systems may also be eliminated if the sows were locked into the stalls during feeding (Andersen et al., 1999).

Other factors affect the extent of injuries, vulva biting and lameness in group-housed sows. A sow's position within the dominance hierarchy can affect her injuries. Sows with lower social status had significantly more injuries one week post-mixing in feeding stall and Electronic Sow Feeding systems (O'Connell et al., 2003). In a feeding stall system, dominant sows received fewer bites. They were also displaced from the feeder less frequently than lower ranking sows. The intermediate ranked sows received the most bites and were displaced most often (Andersen et al., 1999). However, in the same system, Arey (1999) did not find a relationship between the lesions received by sows and their rank in the dominance hierarchy.

The extent of injuries sustained in an Electronic Sow Feeding system is associated with a sow's parity. First to third parity sows received more severe injuries than sows in their fourth parity or higher (Hodgkiss et al., 1998). Similarly, Anil et al. (2004) found that as parity increased, the likelihood of sows sustaining injuries decreased. Heavier sows, which are typically older sows, also sustained fewer injuries (Anil et al., 2003).

Gjein and Larssen (1995a) found that providing bedding was effective in reducing lesions on the vulva in an Electronic Sow Feeding system. In a survey of sow gestation housing systems in England, Rizvi et al. (1998) found that bedding was associated with vulva biting. In a floor feeding system, sows housed on straw sustained significantly more damage to the vulva (Whittaker et al., 1998). Therefore, the type of feeding system may affect that impact that straw has on vulva biting.

Kroneman et al (1993a) found that sows housed on slatted concrete floors were more likely to become lame. Gjein and Larssen (1995b) found more wear and tear on the claws of group than stall housed sows. The condition of the floor can increase the risk of lameness. When concrete floors are poorly maintained or are kept wet and dirty, the risk of group housed sows becoming lame is 2.8 times greater than sows that are housed on clean/dry floors (Gjein and Larssen, 1995b). Andersen and Bøe (1999) found that the

provision of straw significantly reduced the likelihood of group-housed sows becoming lame. Karlen (2005) found that sows housed in stalls, which exposed them to a concrete floor had more severe locomotion problems compared with groups housed sows that were bedded on rice hulls. Thus, although bedding may increase vulva biting in certain group housing systems, it may reduce the number of sows that have to be culled due to lameness associated with flooring.

Lesions scores were three times more prevalent in an Electronic Sow Feeding system than in stalls (Gjein and Larssen, 1995a). Sows housed in stalls had fewer scratches, than sows housed in Electronic Sow Feeding system (Karlen, 2005). Sows housed in an Electronic Feeding System had higher overall injury scores than stall housed sows, because of the aggression at mixing and feeder reset (Backus et al., 2001; Anil et al., 2003).

deKoning (1993) stated that although a sow may have minimal skin lesions, it does not necessarily imply that the welfare of the animal is acceptable, as some of the damage to the integument is due to social interactions. The absence of these lesions means these animals are lacking social interaction, which is an indicator of poor welfare. The level of lesions and leg weakness in stall-housed sows indicates these animals have poor welfare (deKoning, 1993). This study also found that when leg weakness and lesion scores were combined, group housed sows had a lower injury score than stall housed sows.

The longer a sow has been housed in stalls, the more injuries she sustains. According to de Koning (1984), the number of injuries tethered sows received increased, as they grew older. As stall housed sows grew older, their injury scores also increased (Boyle et al., 1999). Karlen (2005) reported that older stall housed sows had more abrasions.

This may be related to the increased size of the sow in later gestation cycle. The length and breadth of a sow, in proportion to the size of the stall, is linked to the severity of injuries. When sows of various sizes were housed in the same size stalls, the shorter and narrower sows sustained fewer injuries (Anil et al., 2002b). Up to 25% of the injuries sustained by stall-housed sows were associated with the length and breadth of a sow, in proportion to the size of the stall (Anil et al., 2002a).

If the strength of the muscles and bones of stall and group housed sows is considered, stall housed sows are more likely to become lame. The decreased muscle mass and bone strength in stall housed sows make the performance of basic movements difficult, which leads to an increased likelihood of them becoming lame (Marchant and Broom, 1994). The decreased muscle strength also strains the muscles, which may result in more conformational problems in sows housed in stalls (Marchant and Broom, 1996a). By the ninth week of gestation, stall housed sows spent a greater percentage of their time lying, and this was likely due to increase leg and hoof problems (Karlen, 2005). It is important to note, that the group housed sows in the study by Karlen (2005) were housed on straw. Other studies too have found that stall housed sows spent a greater percentage of their time lying (Lambert et al., 1983; Boyle et al., 2002). Therefore, even though group housed sows tend to have higher injuries, it does not imply that their welfare is impaired more than stall housed sows.

2.5. Physiology

2.5.1. Reproductive Physiology

In swine, fertilization occurs in the oviduct (Clark, 1990). After fertilization, it takes the embryos three to four days to migrate through the oviduct and reach the uterine horns (Clark, 1990). Upon reaching the uterine horns, the embryos disperse throughout the uterine lumen until approximately the 11th day of gestation. Up to this point in time approximately 10% of the fertilized embryos are lost (Clark, 1990).

Days 12 to 22 of pregnancy are essential for embryonic survival, as it is during this ten-day period that the embryonic tissues begin to elongate and implant into the uterine wall. In addition, between the 11th to 13th days of pregnancy, the dam's body detects the embryonic estrogen released into the uterine lumen. The embryonic estrogen inhibits the uterine wall from secreting prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$), to prevent the corpora lutea from regressing (Stabenfeldt and Edqvist, 1993). During these critical ten days, approximately another 10% of the fertilized embryos are lost (Clark, 1990).

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The rate of embryonic mortality during early gestation varies within the literature. What is clear throughout all the literature is that there is a spike in the embryonic mortality that begins around the 13th day of gestation and then tends to level out by the 25th day of gestation. Table 1.1 is a summary of the findings pertaining to conceptus mortality. The mortality rates were calculated by dividing the total number of corpora lutea by the number of developing embryos (Perry and Rowlands, 1962).

2.5.2. Cardiovascular Physiology

The type of housing system can indirectly influence the heart rate of sows due to the activity that ensues. Stall housed sows have higher basal heart rates and higher heart rates during activities such as feeding, rooting, drinking and lying than group housed sows (Marchant and Rudd, 1993; Marchant et al., 1997). The heart rates of group housed sows decline much faster after feeding than stall housed sows (Geverink et al., 2000). In a later study, stall housed sows had a lower heart rate response to feeding than group housed sows (Geverink et al., 2003).

The elevated cardiovascular rates of stall-housed sows could be a result of a reduced cardiovascular fitness, brought about by a lack of exercise (Marchant and Rudd, 1993; Marchant et al., 1997). The increased heart rate at feeding could also be because the sows anticipate this time of day, and the anxiety they undergo prior to feeding could cause this increase (Marchant and Rudd, 1993; Marchant et al., 1997).

In terms of the cardiovascular differences amongst sows involved in aggressive encounters, Marchant et al. (1995) did not find a difference in the heart rates of the aggressor and recipient. Sows that were involved in physical contact interactions had a higher peak heart rate and larger change in heart rate, than those sows involved in non-physical aggressive encounters. Even so, threats caused an increase in the recipient's basal heart rate levels. However, the increase was not as dramatic (Marchant et al., 1995).

Table 1.1   A summary of the literature pertaining to the extent of conceptus mortality at specific times during gestation

Day of Pregnancy	Conceptus Mortality (%)	Authors
9th	21.4	Scofield et al., 1974
10th	20.8	Lambert et al., 1991
13th	52.4	Scofield et al., 1974
13th to 18th	28.4	Perry and Rowlands, 1962
10th-30th	12.5	Lambert et al., 1991
25th	26	Sorensen and Gosset, 1956
25th	34.8	Perry and Rowlands, 1962

2.5.3. Skeletal and Muscular Physiology

The type of gestation housing system can influence the development of the musculoskeletal system. The development of the muscles required for locomotion was negatively affected when sows were housed in stalls. When the weights of locomotive muscles were compared between stall and group housed sows, the muscles from stall housed sows weighed significantly less (Marchant and Broom, 1996a,b).

When the skeletal systems of stall and group housed sows were compared, the bone strength of stall housed sows was weaker (Marchant and Broom, 1994, 1996a) as well, the length of their spines were significantly shorter (Marchant and Broom, 1996a,b).

There are many reasons for the differences in muscle mass and bone strength. One reason relates to the sows' ability to move within their housing environment. The growth and development of the skeletal and muscular systems is dependant upon the amount that the sows use the musculoskeletal system. Sows in groups tend to move 200 m/d, while stall housed sows only move 130 m/d (McFarlane et al. 1988). Since stall housed sows can only perform forward and backward motions, the muscles are underdeveloped and the bones are weaker (Brouns and Edwards, 1992; Marhcant and Broom, 1996a).

Another reason for the difference in muscle and bone strength between the two types of housing is they may have different maintenance energy requirements. Group housed sows tend to have lower daily energy requirements than stall housed sows, even though they use more energy because they are capable of moving within the pen (National Research Council, 1998). Stall housed sows perform significantly more stereotypies, which may further increases their daily energy requirement (Lambert et al., 1983; Broom et al., 1995; Marchant and Broom, 1996a). Group housed sows are sometimes provided straw, which helps to insulate the sows. The thermal regulatory effect of the straw slightly increases the amount of energy available to the sows and lowers her maintenance energy requirements (Marchant and Broom, 1996a).

Stall housed sows also have a more difficult time with thermoregulation, and may need to use more energy to maintain body temperature, if barn temperatures are not within the sows' Thermal Neutral Zone. They cannot increase their body temperature via movement, huddling or prevent conductive heat loss by resting in straw. Instead, stall housed sows are required to increase their metabolic rate to maintain a desirable body temperature (Brouns and Edwards, 1992; Marchant and Broom, 1996a; Boyle et al., 2002). Gravås (1983) compared the behaviour of stall and group housed sows at less than 14ºC. At that temperature, group housed sows would lie together. They also lay on their abdomen more, while stall housed sows continued to lie on their side. By switching from lateral to ventral lying positions, the group housed sows are better able to regulate heat loss.

Thus, stall and group housed sows have different maintenance energy requirements but are typically fed rations with similar energy concentrations. This results in there being different energy levels available for muscle and bone development. Since group housed sows have lower maintenance energy requirements, they will have more energy available for the development of the muscular and skeletal systems than stall housed sows. As well, the musculoskeletal system is more developed in group housed sows because they used it more, which builds and strengthens the bones and muscles.

Research has found direct evidence to support the fact that housing sows in stalls directly affects their ability to move. Boyle et al. (2002) noted that sows housed in stalls during gestation spent more time standing inactive in farrowing crates than sows housed in groups. The increased time spent standing was thought to be because the sows have difficulty lying down, due to the decreased bone and muscle strength (Boyle et al., 2002). In studies by Marchant and Broom (1993; 1996a), stall housed sows took longer to complete each phase associated with lying. Stall housed sows appeared to struggle when they attempted to lie down. It was especially difficult for larger sows because there was less space available in the stall for them to maneuver into a lying position (Marchant and Broom, 1993). The struggle to change positions may have been what leads to stall

housed sows standing less than group housed sows (Gravås, 1983). The stall housed sows decreased the amount of time they spent standing as they progressed through the gestation cycle. This is likely because the bigger the sows became throughout gestation, the more difficult it became to change position within a stall.

Another potential advantage associated with the ability for group-housed sows to move is the shorter duration and ease of farrowing. Group housed sows needed less assistance during farrowing (Hansen and Vestergaard, 1984) and farrowed in a shorter time period (Vestergaard and Hansen, 1984) than tethered sows. Stall housed sows that were allowed to walk daily also had shorter parturition lengths (Hale et al. 1981; Ferket and Hacker et al. 1985). The shorter duration of parturition and ease during farrowing is likely related to the strength of the muscles, and the muscles are more toned in group housing systems that allow the sows to move.

2.5.4. Stress Physiology

When a pig becomes stressed, it reacts by activating the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS). Stimulation of the hypothalamic-pituitary-adrenal axis results in the release of glucocorticoids, such as cortisol, while the activation of the sympathetic nervous system results in the release of catecholamines (Hay et al., 2000). Once in the blood stream, the glucocorticoids initiate mobilization of energy and tissue nitrogen, increase cardiovascular function, impair the immune system function and inhibit digestion, energy storage, growth and reproduction (Goymann and Wingfield, 2004).

Swine cortisol concentrations follow a circadian rhythm, with concentrations peaking in the morning and declining thereafter (Kunavongkrit et al., 1984; Becker et al., 1985; Mernier-Salaün et al., 1991; Janssens et al., 1995; Zanella et al., 1998; Hay et al., 2000). An increase in the daily concentration is caused by an increase in the activity level, by consuming a meal (Hay et al., 2000) or following a period of food deprivation (Parrott and Mission, 1989).

When the cortisol concentrations of sows that were housed in groups were compared with stall housed and tethered sows, the tethered sows had highest cortisol levels (Barnett et al., 1985, 1987, 1988, 1989; Friend et al., 1988). The circadian rhythm of the tethered sows was disrupted as the cortisol concentration of the gilts continued to rise after the typical morning peak (Barnett et al., 1985). Thirty minutes after gilts were tethered or moved into individual pens, the serum cortisol concentration of the tethered gilts was 152% higher than the concentrations recorded in the individual pens. Eleven and half hours after introduction, the cortisol concentrations of the tethered gilts was still 90% higher than the concentrations recorded in the gilts housed in individual pens (Becker et al., 1985). A study by Barnett et al. (1985), confirmed that tethered sows had higher cortisol concentration than floor fed sows. The degree of the cortisol increase in tethered sows is severe enough to directly implicate that the welfare of sows that are tethered is in jeopardy (Barnett et al., 1988).

Other evidence of cortisol differences associated with housing type is contradictory. Stall housed gilts had lower cortisol concentrations than gilts housed in a group and fed at a trough without dividing partitions (Geverink et al., 2000, 2003) or in an Electronic Sow Feeding system (Karlen, 2005). Other studies found that stall housed sows had higher cortisol concentrations than group housed sows (Salak-Johnson et al., 2005), but not until the sows had acclimated to the Electronic Sow Feeding System (Jensen et al., 1995). Before the sows acclimated to group housing, the sows in stalls had a lower plasma cortisol concentration. One week post-mixing, the group housed sows still had higher cortisol levels than stall housed sows (Jensen et al., 1995). However, Vermeer et al. (2000) and Backus et al. (2001) did not find a difference in the salivary cortisol concentrations of sows housed in stalls or in Bio-Fix, feeding stall and Electronic Sow Feeding systems.

The regrouping of sows causes elevated cortisol levels, which is why the group housed sows initially had higher cortisol concentrations than stall housed sows in the study by Jensen et al., (1995). Barnett et al. (1996) found that plasma cortisol concentrations increased as the number of aggressive interactions at mixing increased. In an Electronic Sow Feeding system, the cortisol concentrations increased as the sows initiated and received more aggressive encounters (Anil, 2004). Salivary cortisol

concentrations were also significantly higher the day after mixing than they were two weeks after mixing in an Electronic Sow Feeding system (Anil et al., 2005b). Sows fed at a feed trough without dividing partitions, underwent a temporary disruption in the circadian rhythm the day of mixing (Pedersen et al., 1993). However, Tsuma et al. (1996b) found that plasma cortisol concentration returned to pre-mixing levels the day after mixing, when sows were fed at a trough without dividing partitions. In weaned piglets, the stress of relocation and mixing resulted in increased salivary cortisol concentrations. However, they returned to basal concentrations eight hours after mixing (Merlot et al., 2004). Therefore, when sows are regrouped, the new environment may also cause an increase in the cortisol levels of sows.

There is evidence that suggests there may be a psychological component to the increased cortisol concentrations at mixing. When aggression amongst boars at mixing was examined, Parrott and Mission (1989) found that involvement in aggressive encounters was not a precursor to the elevation of salivary cortisol, as boars that were not involved in aggressive encounters had elevated cortisol concentrations. The cortisol levels also remained elevated for several days after mixing; even after the aggression levels had become minimal (Parrott and Mission, 1989). This provides evidence that the elevation in cortisol after mixing is a result of a psychological as well as physical stress.

The increased physical activity and ability to interact with conspecifics may also have caused the higher cortisol concentrations in the group housed sows (Friend et al., 1988; Geverink et al., 2003). The lower cortisol concentrations seen in the stall-housed sows may be due to the chronic stress brought on by the restrictive housing (Geverink et al., 2003).

A sow's rank within the dominance hierarchy can impact cortisol concentrations. However, which sows within the hierarchy are most affected varies throughout the literature. Tsuma et al. (1996b) found that it was the intermediate sows within the dominance hierarchy who had the lowest cortisol concentrations on days two and three post-mixing. These sows were fed at a trough that did not have a dividing partition. Zanella et al. (1998) found that the dominant and subordinate sows in an Electronic Sow

Feeding system had the lowest levels of cortisol. The intermediate ranked sows had the highest cortisol levels. In weanling pigs, it was the pigs that held a higher position in the dominance hierarchy that had lower cortisol concentrations three hours after mixing (Merlot et al., 2004).

Otten et al., (1997) observed the most significant increase in their cortisol levels in dominant sows, especially when they encountered unfamiliar sows. The dominant sows also had higher heart rates and elevated catecholamine concentrations during the first 30 minutes after mixing. However, those same sows were involved in more social encounters which may have activated the sympathetic nervous system and would cause increased catecholamine release and a quickened heart rate (Otten et al., 1997).

A study by Pedersen et al. (1993) did not find a difference in the cortisol concentrations of low, intermediate and high-ranking sows, when they were fed at a trough without dividing partitions. O'Connell et al. (2003) did not find a difference in salivary cortisol levels between dominant and subordinate sows on the day of mixing and one week later, in feeding stall and Electronic Sow Feeding systems. When examining aggression in stalls and tethers, the sows that withdrew more, (i.e. the subordinate sows), were the sows with the higher cortisol levels (Barnett et al., 1989).

It remains unclear how rank affects cortisol. Which sows within the group are undergoing the most stress will vary with each housing system, as each has their own management strategies that can amplify or minimize stress.

2.6. Productivity

A primary concern of producers is the productivity of their pigs, which is indicative of the efficiency of the housing systems. It is generally accepted that a non-stressed, healthy pig will be a productive pig. Thus, studies commonly compare the farrowing results of group and stall housed sows.

Some studies have found that sows housed in groups are more productive than those in stalls are. A greater percentage of sows remained pregnant when housed in an Electronic Sow Feeding System (Bates et al., 2003). This resulted in these sows having a higher farrowing rate than stall housed sows (94.3% vs. 89.4% for group and stall

housed sows respectively). Friend et al. (1995) found overall that group housed sows had more piglets born alive compared with stall-housed sows. Sows housed in an Electronic Sow Feeding system weaned more piglets per sow than stall housed sows (Karlen, 2005). Sows housed in an Electronic Sow Feeding System also had heavier piglets and fewer runts and deformities resulting in death (Korthals, 1982). Gravås (1983) found that group housed sows had more total born piglets, but more stillborn piglets. However, a later study by Bates et al. (2003) found that sows housed in an Electronic Sow Feeding system had slightly fewer stillborn piglets than stall housed sows.

Sows housed in an Electronic Sow Feeding system have a shorter wean to service interval than stall or tether housed sows (Korthals, 1982). The wean to service interval was a quarter of a day shorter in sows that were floor fed (Schmidt et al., 1985) or housed in an Electronic Sow Feeding system (Korthals and Bates, 1998).

Some studies have found that there is not a difference in the farrowing productivity amongst different housing systems. There was not a significant difference in the total number of piglets born and the number of piglets born alive, on a per sow basis, between sows housed in the Electronic Sow Feeding System or stalls (Singleton, 1989; Vermeer et al., 1999 Korthals, 1982; Boyle et al., 2002; Bates et al., 2003). Another study did not find a significant difference in the number of piglets born alive per litter in feeding stalls, Electronic Sow Feeding, Bio-fix and stall housing systems (Backus et al., 2001). Hansen and Vestergaard (1984) did not find a significant difference in the number of piglets born alive per litter or stillbirths per litter between sows group housed and those that were tethered. In addition, Singleton (1989) did not find a difference in the litter weight, weaning weight or number of piglets weaned between stall and group housed sows. Backus et al. (2001) noted that piglets born from sows housed in an Electronic Sow Feeding system had the lowest birth weight but had the highest weaning weight. Another study found that when the sows were housed in an Electronic Sow Feeding system, the birth weight of the piglets was higher than those of stall housed sows and this trend was found in the weaning weights (Bates et al., 2003).

Other studies have found poorer performance in group-housed sows. Stall housed sows had a higher farrowing rate than group housed sows in a study by Karlen (2005). Friend et al. (1988) found that the largest litter sizes were farrowed by tethered sows. Sows that were housed in stalls had more piglets born alive per sow (Marchant and Broom, 1996a) and more piglets born alive per year (den Hartog et al., 1993) than sows that were housed in an Electronic Sow Feeding system. The impaired productivity of the group housed sows may be due to the stress and fear brought about by mixing unfamiliar sows and housing sows at high stocking rates (Kongsted, 2004).

The type of group-housing system does not affect the farrowing productivity. There was not a significant difference in the average number of piglets born alive for sows housed in the free access stall, trickle feeding, or Electronic Sow Feeding systems (Vermeer et al., 1999). Backus et al. (2001) did not find a difference in the number of piglets born per litter in sows housed in feeding stall, Bio-Fix and Electronic Sow Feeding systems.

Stress is a concern in gestating sows because the negative repercussions associated with stress not only affects the sow, but also can negatively affect the fetuses. When the circulating concentrations of cortisol are elevated, a portion of the excess cortisol reaches the uterine lumen. The increased cortisol in the uterus is of concern because it may alter the environment within the uterus and affect the embryos' ability to attach to the uterine wall (Behrens et al., 1993; Tsuma et al. 1996a). It is before and during embryonic implantation that the increased cortisol due to stress may affect embryonic survival. Mixing is considered a stressful time for sows and it could potentially affect the sows' productivity. Edwards (1998) recommended avoiding mixing sows 10 to 14 days post-breeding. According to Edwards (1998), the ideal time to mix sows is four weeks after the sow has been bred.

Bokma (1990) found that mixing sows before embryonic implantation caused the return to estrus rate to increase 10% higher than the 10% return rate for sows mixed after implantation. This same study also found that 0.2 fewer piglets were born per litter when the sows were mixed before implantation. A later study found that the difference in number of piglets per litter was actually 0.5 fewer piglets born to sows mixed before 4 weeks post-breeding (Mortensen, 2000). Sows mixed 30 days after breeding had a 10%

higher farrowing rate than the sows that were mixed shortly after breeding (Hurtgen et al., 1980). Mendl et al. (1992) found that dominant sows within a group were experiencing the lowest stress levels within the group, and it was the dominant sows that had heavier piglets at farrowing (Mendl et al., 1992).

Other studies examining other forms of stress have also found negative effects on the sows' productivity. Negative handling was stressful for gilts as indicated by the elevated cortisol concentrations. Subsequently, the negatively handled gilts had lower farrowing rates (Hemsworth et al., 1986).

Edwards et al. (1968) found that sows that were heat stressed 1 to 15 days post-breeding had significantly fewer viable embryos and lower embryonic survival rates than those kept within the thermal neutral zone. Sows that experienced heat stress (36.7°C) from days 1 to 5 of pregnancy had half as many viable embryos as the control sows. Embryonic survival was not affected when sows underwent heat stress on day 20 of pregnancy (Tompkins et al., 1967). Wildt et al. (1975) exposed sows to 40ºC temperature every second hour on days 2 to 13 or 14 to 25 of gestation. Sows that were heat stressed before embryonic implantation (days 2 to 13 of gestation) had a significantly higher embryonic mortality rate than the control sows. What was interesting was that sows that were heat stressed during the embryonic implantation (day 14 to 25 of gestation) did not undergo an increase in embryonic mortality. These studies show that the embryos are actually the most vulnerable before they implant into the uterine wall, not while they are undergoing the implantation process.

Other studies suggest that stress during implantation does not negatively affect the sow's productivity. Tsuma et al. (1996b) mixed sows 11 days post-breeding and embryonic survival was not affected, when the embryos were collected on day 17 of pregnancy. The stress associated with feed deprivation on the 13th and 14th day of gestation, did not cause an increase in embryonic mortality (Razdan et al., 2001). Exposing sows to heat stress after breeding did not reduce the embryonic survival from day 3 to 24 of gestation (Liao and Veum, 1994).

After the key period of embryonic implantation, Klemcke (1995) found that on the 50th day of pregnancy, 23% of the cortisol an embryo was exposed to was from the dam. By the 100th day of pregnancy, the dam contributes only 6% of the fetuses'

exposure to cortisol. The fetus has developed methods of preventing maternal cortisol from over saturating the placenta (Klemcke, 1995). Thus, after the embryo has attached to the uterine wall, the increase in maternal cortisol does not significantly affect the developing embryo.

2.7. Conclusions

Grouping housing for gestating sows is a viable option in terms of welfare and productivity. However, with each different group housing system, there are different issues that arise. In an Electronic Sow Feeding System, the aggression at feeding is a serious concern, because of the competitive environment created at the feeder station. The aggression at mixing is also one of the most common concerns associated with group housing sows.

The timing of the introduction of the sows into group housing is also of concern. If the sows are mixed before or during embryonic implantation, they undergo a loss in productivity. However, it has not been determined if there is a behavioural association to the loss in productivity when sows are mixed pre-implantation.

There are other variables within the group environment, like familiarity with the pen mates and the parity, that affect the behaviour of the sows. Therefore, this study examined how stage of gestation, familiarity and parity affect the behaviour, welfare and productivity of sows housed in static and dynamic management systems.

3. SOCIAL FACTORS THAT AFFECT THE BEHAVIOUR AND PRODUCTIVITY OF GESTATING SOWS IN AN ELECTRONIC SOW FEEDING SYSTEM

3.1. Introduction

The rationale behind this study was to assess social and behavioural factors that may have contributed to the differences in productivity seen in a previous study at PSC Elstow Research Farm (Li, personal communication). In that study, it was found that the farrowing rate differed based upon the management of the Electronic Sow Feeding housing system. These differences were attributed to whether the sows were housed in static or dynamic pens, mixed before or after embryonic implantation, and the parity of the sow.

The farrowing rates for gilts were approximately 12% lower than the rates of the first parity and older sows. There was some indication that mixing gilts pre-implantation was less detrimental in a dynamic system, while the farrowing rates of sows in their second parity or higher were better in a static than a dynamic system (Li, personal communication).

Mixing the sows post-implantation resulted in an 8% improvement in the farrowing rate over the sows that were mixed pre-implantation. The difference between mixing sows pre- or post implantation was consistent for all ages (Li, personal communication).

Previous research has also found that sows that are familiar with the pen mates at mixing are significantly less aggressive (Olsson and Samuelsson, 1993; Jensen and Yngvesson, 1998). Therefore, whether or not a sow was familiar or unfamiliar with the majority of her penmates was also examined.

Thus, objective of this experiment was to determine how housing management, stage of gestation, familiarity and parity affected the behaviour, salivary cortisol concentrations and productivity of sows housed in an Electronic Sow Feeding system.

3.2. Materials and Methods

3.2.1. Treatment

This study was conducted at the PSC Elstow Research Farm between May and November of 2004; using 293 PIC sows (Pig Improvement Company Canada). The sows' ranged from first to ninth parity. Before mixing, young sows weighed on average 196.4 kg (range 161 to 344 kg), intermediate sows averaged 242.6 kg (range 196 to 381 kg), and old sows averaged 289.5 kg (rang: 229 to 333 kg).

The experimental design was a split plot with two housing management treatments (Static vs. Dynamic) in the main plot (4 reps each), and a 2x2x3 factorial arrangement of stage of gestation (2), familiarity (2) and parity (3) in the sub-plot. All the sows were group housed and fed in an Electronic Sow Feeding station.

The dynamic housing treatment consisted of approximately 100 sows, from three different introduction groups, housed in a large pen with three Electronic Sow Feeding stations. Every five weeks, a group of approximately 35 resident sows was removed for farrowing, and the following day a new group of sows was introduced into the dynamic pen. Hence, the term dynamic housing system refers to a group of individuals coming and going into a resident group. While on test, the sows in the dynamic housing system underwent one subsequent regrouping five weeks after their initial introduction to the group.

In contrast, the static pens housed approximately 35 sows added to the pen at the same time. A static group remained stable throughout gestation, as new sows could not be added to the group after the initial mixing. Sows assigned to the static management treatment were housed in one of two static pens. Figure 3.1 is a schematic diagram of a

24.3 m

8.1 m

4.0 m

Dynamic

Static

5.6 m

Slatted Floor

Feeder

Boar Pen

Divider Penning

Solid Floor

• 2 Drinkers
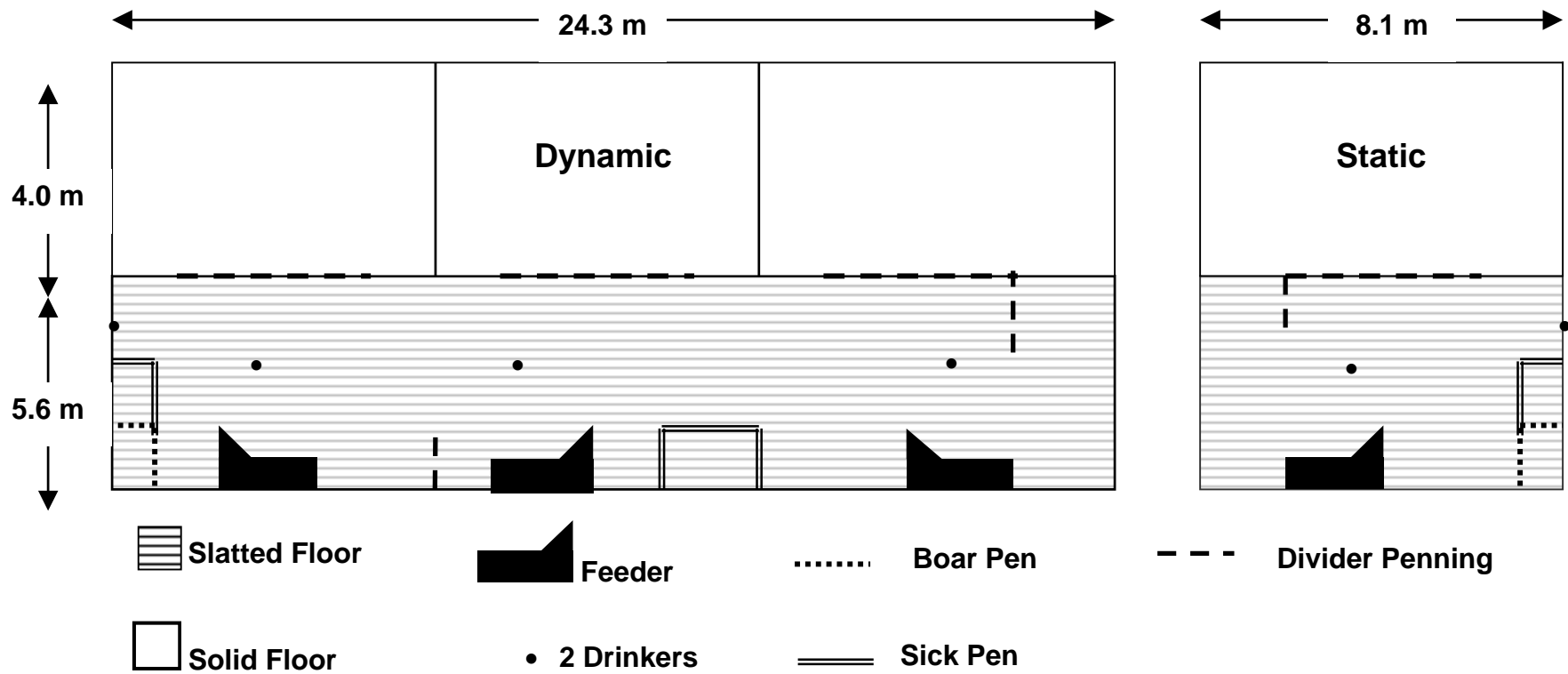
Sick Pen

∗ **The dimensions of boar and sick pens are 3.0 x 1.81 m**

Figure 3.1   A schematic diagram of a static pen and dynamic housing system.

static pen and the dynamic housing system. Upon the removal of the post-implant sows for farrowing, in both the static and dynamic housing management systems, the pre-implant sows remained in the pen until they were due to farrow.

Stage of gestation compared sows regrouped either during or after embryonic implantation. Pre-implant sows entered group housing on average 12 days post-breeding (range 5 to 15 days), while the post-implantation sows entered group housing approximately 46 days post-breeding (range 38 to 50 days). Each group introduced to either the static or dynamic management treatment, consisted of a combination of pre- and post-implant sows. If a sow was assigned to the post-implantation classification, the sow was selected five weeks in advance and housed in a stall after breeding until she was to be regrouped.

Sows were classified as familiar or unfamiliar based on the relative proportion of sows in the current introduction group that they were housed with during the previous gestation cycle. A sow in the familiar category was housed with an average 23.5% (range 18.1% to 32.3%) of her current pen mates in the previous gestation cycle. Sows classified as unfamiliar had been housed with an average of 8.6% (range 6.7%; to 12.5%) their current pen mates in the previous gestation cycle.

The length of time the sows were apart for farrowing and rebreeding was dependant upon whether the sows were mixed pre- or post-implantation. Pre-implant sows were separated for approximately 4.7 weeks when they were mixed. The post-implants were apart for approximately 9.6 weeks at mixing, because they were housed in stalls during embryonic implantation.

The final comparison was parity; first parity sows were classified as young, second and third parity sows were grouped into an intermediate category, while sows in their fourth parity or higher were classified as old.

In the static and dynamic housing management systems, each introduction group consisted of 34 to 44 sows, depending upon the sow flow of the production unit. Within each introduction group, up to 24 focal sows were selected based on the three criteria; stage of gestation, familiarity and parity. Overall, there were 12 possible treatment

categories, and if available, two sows were chosen for each treatment category, resulting in up to 24 focal sows being chosen. The number of sows for used in each of the twelve treatment categories in outlined in Figure 3.2.

The data for this study was only collected from the focal sows. For each of the 12 treatment categories, if there were two sows available, the average values were used in the analysis. Each focal sow was assigned a number representative of her treatment. For individual identification of the focal sows, the number was spray painted on her back and on both sides of her abdomen.

3.2.2. Animals and Housing

A minimum of 2.0 m^2 of space per sow was provided in both housing management systems. This space allowance corresponds to the space allowance of 2.1 m^2 per sow (for sows weighing between 200 to 250 kg) suggested by the Recommended Code of Practice (AAFC, 1993). The group housing pens had partially slatted floors. A solid plastic partition separated the solid areas between two pens, while iron spindle penning separated the slatted areas. Spindle penning also created a barrier between the solid and slatted areas within a pen. The ventilation and temperature were artificially controlled. The lighting regime ran on a fourteen-hour light (06:20 to 20:20h), ten-hour dim lighting schedule.

Immediately following weaning, the sows were moved into stalls for breeding. After breeding, the sows were moved either into another stall or into group housing, depending on their stage of gestation treatment. Mixing took place mid-morning, after the sows were fed. The sows had access to the feeder immediately upon entering group housing.

An Electronic Sow Feeding System (Insentec B.V., Marknesse, The Netherlands) was used in this study. All the sows in the study had prior experience with this feeding system for during the previous gestation, at a minimum. The feeder station design was such that the sows entered the feeder at the rear and exited through a short alleyway at

Static

	Pre-implant	
	Fam	Unfam
1st	6	8
$2^{nd}/3^{rd}$	8	8
$4^{th}+$	4	7

	Post-implant	
	Fam	Unfam
1st	8	8
$2^{nd}/3^{rd}$	7	8
$4^{th}+$	5	7

Dynamic

	Pre-implant	
	Fam	Unfam
1st	8	8
$2^{nd}/3^{rd}$	5	8
$4^{th}+$	8	8

	Post-implant	
	Fam	Unfam
1st	6	8
$2^{nd}/3^{rd}$	8	7
$4^{th}+$	7	7
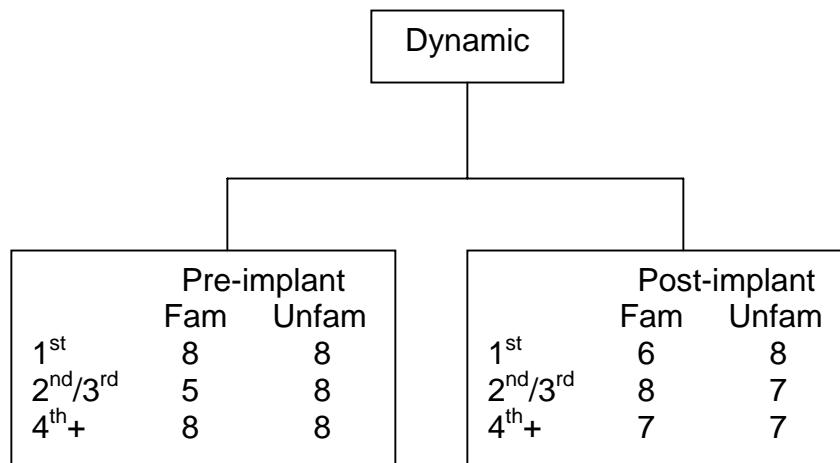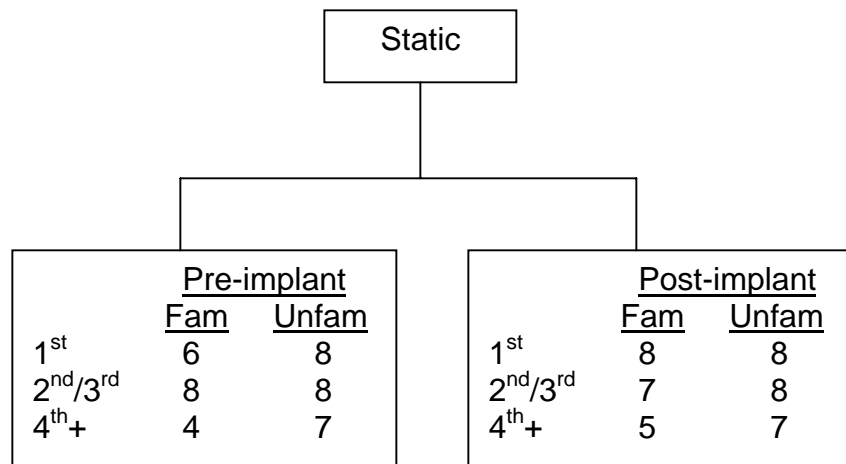
Figure 3.2 The number of focal sows studied for each for the twelve treatment combinations in the static and dynamic housing management systems.

the front of the feeder. Once a sow entered the Electronic Sow Feeding station, the rear gate was equipped with a lock out feature that prevented sows from entering while a sow consumed her meal. Figure 3.3 illustrates the layout and dimensions of an Electronic Sow Feeding station.

The feeder reset daily at 15:00 h, at which time a list of sows that had not consumed all of their daily feed allotment was generated. Feed was dispensed in 100 g portions approximately every 30 s. A small amount of water was released into the trough every time feed was dispensed. Sows had a predetermined amount of time to consume their feed before the feeder's gate unlocked to allow another sow in the feeder. This time limit was adjustable to provide slower eating sows ample time to consume their daily feed allowance without being disturbed. All the sows were fed a standard gestation diet that was formulated to meet or exceed NRC (1998) requirements.

The diet contained approximately 55% barley, 21% wheat and 15% peas. The digestible energy content of the diet was 3149 kcal/kg, and contained 15.38% crude protein and 0.45% digestible lysine (4.51 g Dlys/Mcal DE), and had sufficient vitamin and minerals to meet requirements (NRC, 1998). The amount allocated per sow varied based on parity, body condition and stage in gestation. The sows were fed on average 2.9 to 3.9 kg of feed per day.

3.2.3. Data Collection

3.2.3.1. Aggression Post-Mixing

The aggression that took place immediately after mixing was recorded via live observations. Continuous observations were made during the four-hour period immediately following the introduction of the last sow into the pen. All aggressive encounters involving focal sows were recorded. An aggressive encounter was composed of one or more of the following behaviours: parallel and inverse parallel pressing, head-to-head and head-to-body knocks and levering. Table 3.1 is an ethogram of the aggressive behaviours examined in this experiment.
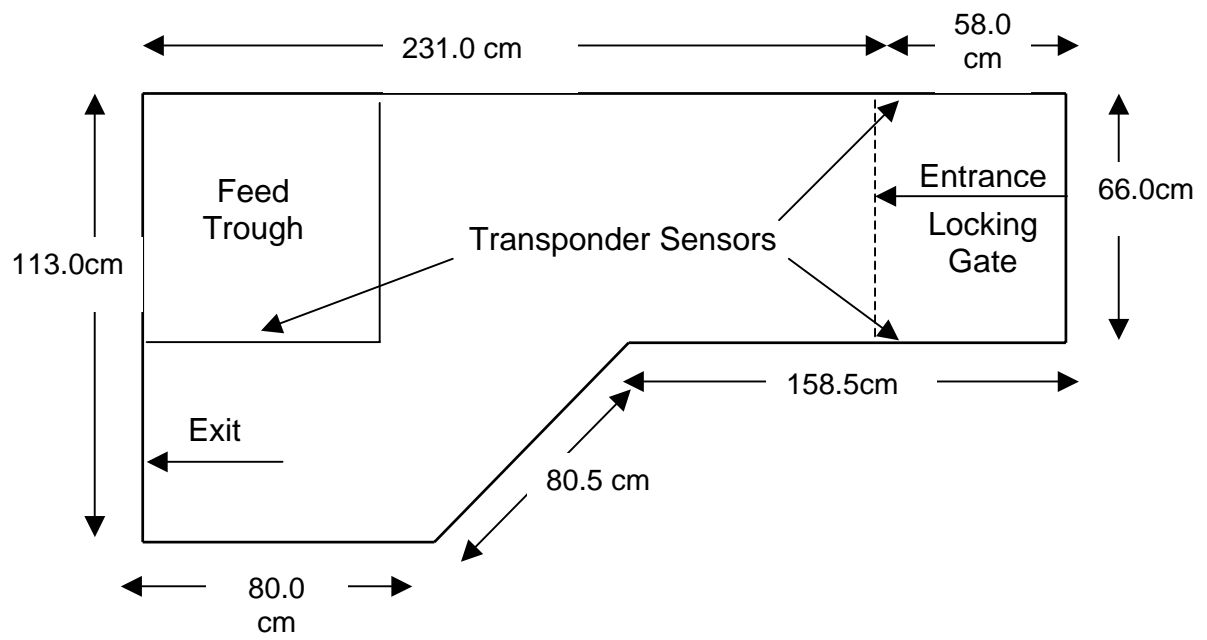
Figure 3.3 An overhead view of the layout and the dimensions of an Electronic Sow Feeder station.

Table 3.1   An ethogram of aggressive behaviours examined post-mixing and at the entrance of the Electronic Sow Feeding station[1]

Behaviour	Description
Parallel pressing	Sows stand side by side and forcefully push against one another, while swinging their head and possibly biting the neck or head of the other sow
Inverse parallel pressing	Same as parallel pressing but the sows are facing opposite directions, thus the head thrusts and bites are directed at the flank of the other sow
Head-to-head knock	The sow rapidly thrusts her head or snout in an upward or sideways directions towards the neck, head or ears of another sow (this may involve a bite)
Head-to-body knock	Same as a head-to-head knock except it is directed at any part of the body behind the ears
Levering	A sow lifts another sow into the air by standing behind the sow and placing her snout under the body of the other sow
Nosing	A sow makes short physical contact, by placing her nose on the nose, head, ears, body or anal-genital region of another sow

[1] Modified from Jensen (1980)

The identities of the focal sows involved in the aggressive encounters, and the duration of the encounters were recorded. If one of the sows involved in the aggressive encounter was not a focal animal, the interaction was recorded, with an indication that one of the sows was not a focal sow. From the data collected, the total duration and average duration of the aggressive encounters and the total number of aggressive encounters a sow was involved in were calculated.

3.2.3.2. Aggression at the Feeder

Aggression at the feeder was recorded by a video camera located above the entrance of the Electronic Sow Feeding Station. The camera was connected to a time lapse VCR (Panasonic AG6730 or AGTL950). One 100-watt light bulb located above the feeder provided lighting during the recording. Recording began at 15:00 h, when the feeder reset, and ended at 06:00 h the following day. Based upon previous observations, the amount of activity at the feeder was negligible at 06:00 h; hence, aggressive observations were not made during this time.

The observation period was divided into 3 periods: period 1 (15:00 to 19:00 h), period 2 (19:00 to 23:00 h) and period 3 (23:00 to 06:00 h). Aggression at the feeder was recorded on days 1, 3, 28, and 63 post-mixing.

From the videotapes, all occurrences of aggressive encounters that occurred within a 2.4 m (length) and 1.7 m (width) area within the feeder entrance were recorded. The identity of the sows that initiated and received the aggression was recorded. An aggressive encounter was composed of any of the following behaviours: levering, head-to-head and head-to-body knocks and the nosing of the body or anal-genital region (Table 3.1).

3.2.3.3. Injury Scores

Injury scores were assessed visually to determine the extent of damage caused by aggression for each sow. During the injury scoring process, a scratch score and an other injury score were recorded. A "total injury score" was calculated by adding the scratch and other injury scores.

The scratch score was composed of two regional scores. One measured the magnitude of scratches the sows sustained to their head, ears and shoulders. The second scratch score measured the scratches sustained on the flanks, abdomen, udder, thighs and limbs. The scale used to score scratches is described in Table 3.2. All detectable fresh and healed scratches were included when scoring the scratches. The scratch score used for the data analysis was an overall scratch score. The overall scratch score was calculated by adding together the two scratch regional scores, thus the highest possible scratch score was six. Even though the scratch score discussed later on is the overall scratch score, it will be referred to as the scratch score from this point forward.

The other injury score measured the prevalence and severity of cuts, swellings and abscesses on the head, ears, shoulders, abdomen, thighs, limbs, udder, tail and vulva. The scoring system for cuts, swellings and abscesses is described in Table 3.2. Eighteen regions of the body were scored; with the highest possible score for each region being six and the highest possible other injury score being 108. While the injuries were assessed, the mobility of the sows was assessed and score. The scoring system used to assess lameness score is in Table 3.2.

Throughout the study injuries and lameness was assessed six times in total. The scoring was conducted before mixing the sows (day 0), as well as days 3, 28 and 63 post-mixing. The assessments were also conducted when the sows entered the farrowing room (referred to as farrowing) and after the sows had been in the farrowing room for two weeks (referred to as lactation). Body weight was recorded the day of weaning (pre-mixing weight) and before farrowing.

Table 3.2   The scoring system used to assess scratches, cuts, swellings, abscesses and lameness present on sows in an Electronic Sow Feeding system.

Score	Injury					Lameness
	Regional Scratch Score	Components of the Other Injury Score				
		Cuts	Swellings	Abscesses		
0	No scratches	No cuts	No Inflammation	Previous wound healed (scar)		Not lame
1	1 to 3 scratches	Minor cut: no flesh exposed	Inflammation, slight swelling	Presence of a scab		Slightly lame: could not bare full weight on leg
2	4 to 6 scratches	Major cut: can see flesh	Marked swelling	Open wound		Lame: can not put weight on one leg
3	7 or more scratches	-	-	-		-
Highest Possible Score*	6	36	36	36		2

* This is the highest possible score a sow could have received for scratches (two regions, highest regional score= 3) and for other injuries (18 regions, with the highest regional score= 2).

3.2.3.4. Feeder Entry Order

Feeder entry order was obtained by videotaping the "Feeder Status" option within the Electronic Sow Feeder computer program. Recording began when the feeder reset at 15:00 h and ended the following morning at 09:00 h. The feeder entry order was recorded the day after mixing (day 1) and on day 3, 28 and 63 post-mixing. Once the order was obtained, the first focal sow to enter the feeder was scored a zero, while the last sow to eat was scored a one. The remainder of the sows were assigned a fraction for their entry order based on where they were in the order and how many focal sows ate that day. The following formula was used to calculate the feeder entry order:

$$\text{Feeder Entry Order} = p/n\text{-}1 \qquad\qquad (3.1)$$

Within the formula, n equals the number of focal sows that ate that day and p is the sow's numerical position within the order. For example, if 18 sows entered the feeder, the sixth sow to enter the feeder would have a feeder entry order of 0.35 (6/(18-1)). One was subtracted from the total number of sows in the pen so that the first sow that ate was assigned 0 and the final sow's entry order equaled 1. The lower the feeder entry score, the earlier in the feeding cycle she ate.

3.2.3.5. Salivary Cortisol

Salivary cortisol samples were collected to assess the stress level of the sows. Three days before mixing, a sample was collected while the sows were in stalls. This sample provided an estimate of the sows' cortisol levels before mixing. Then on days 1, 2, 3, 28 and 63 post-mixing, saliva samples were collected to determine the stress of mixing and group housing. Sample collection began at a consistent time each day (13:00 h), in order to minimize the effects of the diurnal fluctuation in cortisol. A sample was collected by placing an absorbent cotton swab attached to floss into a sow's mouth. The swab remained in the sow's mouth until the swab was saturated with saliva, or until the sampler had been attempting to obtain the sample for two minutes.

The salivary cortisol analysis was conducted at the Alberta Agriculture and Food Research Station in Lacombe, Alberta. The assay carried out was a competitive enzyme immunoassay (Cook et al., 1997). In this assay, there are a limited number of antibody binding sites; cortisol from the test sample (saliva) competes with cortisol (cortisol-3-horseradish peroxidase (F-3-HRP)) that has been labeled with the enzyme (tetramethyl benzidine or TMB). The antibody is attached to the wall of the sample well and was raised against a cortisol-3-bovine serum albumin (F-3-BSA) conjugate. The plate contained 96 wells, into which nine cortisol standards, 6 internal quality controls and 33 samples were added. All of the samples, standards and quality controls were analyzed in duplicate. The inter-assay precison was calculated from the repeated analysis of quality controls. The concentration of the quality controls were 25.55, 12.26 and 5.96 ng/mL, with inter-assay coefficients of variation of 11.6%, 15.6% and 38.6% respectively.

3.2.3.6. Lying Patterns

The resting locations of the focal sows within the pen were recorded at 09:00 h for three consecutive days the week of mixing (week 0), and three and eight weeks post-mixing. If a sow was lying, her location was recorded as against the wall, or in the open area (centre) of the solid portion of the pen, or on the slats. The identity of sows that were standing was also recorded at this time. The lying patterns were recorded to determine how space usage differed amongst each of the treatments, as the preferred area in the pen to rest in on solid areas, and more specifically against the wall.

For the data analysis, the three days were converted into a weekly average for each of the areas of interest for each sow. The proportion of the observations the sows spent resting on either the solid or the slats was considered exclusive of standing. Therefore, the total amount of time sows spent lying in the three areas totaled 100% unless the sows did not spend any time lying in any of the three locations. The percentage of time that sows spent standing was calculated by the following formula:

% of Time Standing= n/3*100   (3.2)

with n equaling the number of times a sow was observed standing during a specific week.

3.2.3.7. Farrowing Productivity

The farrowing rates, total piglets born and number of piglets born alive were recorded for the focal and non-focal sows in the experiment.

A separate analysis was carried out on data previously collected at the PSC Elstow Research Farm. The number of days after breeding when 427 pre-implant sows entered group housing was analyzed to determine if the number of days post-breeding at the time of introduction into group housing affected the farrowing rate.

3.2.4. Statistical Analysis

The model used in the statistical analysis was similar for all variables examined. However, there was variation in the degrees of freedom and how many sub-plots were examined for each parameter. The model used for the statistical analysis is shown in Table 3.4. The statistical analysis was limited to two and three-way interactions. The statistical analyses were conducted using SAS statistical software (SAS Inst., Inc., Cary, NC.).

The residual dataset was tested for normality using the univariate procedure in SAS. If the data was not normally distributed the appropriate transformations were made to the raw data. The data presented in the tables and figures is from the raw dataset. However, the P-values used to indicate the statistical significance are from the transformed dataset.

3.2.4.1. Aggression Post-Mixing

The number of aggressive encounters, as well as, the total and average duration of aggressive encounters that occurred post-mixing were analyzed using the Mixed Procedure of SAS. The model was a split plot with housing as the main plot and implantation, familiarity and parity treatments as the split plot (Table 3.3; column A). Of

the three variables examined, none were normally distributed. The total and average duration of aggressive encounters were transformed by taking the cube root, while the number of aggressive encounters was transformed using log 10 plus one.

3.2.4.2. Aggression at the Feeder

The number of aggressive encounters initiated and received at the feeder were not normally distributed, thus both were transformed by taking the cube root of the cube root. The data was analyzed according to a multiple split plot model (Table 3.3; column F), using the Mixed Procedure of SAS. The main plot of the model was housing with the effects of implantation, familiarity and parity (first sub-plot), day (second sub-plot) and time of day (third sub-plot) nested within housing.

3.2.4.3. Injury Scores

The total injury score were normally distributed, while the scratch score and the other injury scores were not and were transformed by the sine function and log 10 plus 1 respectively. The three data sets were analyzed according to a multiple split plot model (Table 3.3; column C), using the Mixed Procedure of SAS. Housing was the main plot of the model, the first sub-plot was composed of implantation, familiarity and parity and the second sub-plot was days post-mixing.

The body weight data was normally distributed and was analyzed using the model in column E in Table 3.3. The lameness was analyzed using the General Model procedure for SAS.

3.2.4.4. Feeder Entry Order

Feeder entry order was normally distributed and was analyzed as a multiple split plot model using the Mixed Procedure. The main plot and first sub-plot were the same as those used to analyze injury scores. The variation in the models was the second sub-plot, the time, as fewer observations were made for feeder entry order (Table 3.3; column B).

3.2.4.5. Salivary Cortisol

The data for salivary cortisol underwent the log 10 transformation before analysis. The data analysis is identical to the methodology used to analyze the injury score data (Table 3.3; column C).

3.2.4.6. Lying Patterns

The data for sows lying on the solid floor against the wall or in the center, lying on the slats and standing were all normally distributed. The data was analyzed using the Mixed Procedure of SAS according to a multiple split plot model (Table 3.3; column D). The main plot of the model was housing, implantation, familiarity and parity (first sub-plot), and week (second sub-plot), which were nested within housing.

3.2.4.7. Farrowing Productivity

The total number of piglets born per litter and the number of piglets born alive per litter, were both normally distributed and were analyzed using the same model used to analyze the data from the aggression that occurred after mixing (Table 3.3; column A).

The farrowing rates for the main effects and the two-way interactions were analyzed using the General Model procedure for SAS. This model for farrowing rates assumes that the data is not normally distributed. A General Model procedure was used to determine if the number of days that elapsed after breeding before a sow entered group housing significantly affected the likelihood of her farrowing.

Table 3.3 Split plot used to analyze aggression post-mixing, farrowing rate, total born and born alive (A), and the multiple split plot aggression used to analyze feeder entry order (B), injury scores, lameness, salivary cortisol (C), lying patterns (D), body weight (E), aggression at the feeder (F).

Variable Tested	Degrees of Freedom					
	A	B	C	D	E	F
Housing	1	1	1	1	1	1
Group(House)[a]	6	6	6	6	6	6
Treatment Subplot						
Implantation	1	1	1	1	1	1
Familiarity	1	1	1	1	1	1
Parity	2	2	2	2	2	2
Housing*Implantation	1	1	1	1	1	1
Housing*Familiarity	1	1	1	1	1	1
Housing*Parity	2	2	2	2	2	2
Implantation*Familiarity	1	1	1	1	1	1
Implantation*Parity	2	2	2	2	2	2
Familiarity*Parity	2	2	2	2	2	2
House*Implantation*Familiarity	1	1	1	1	1	1
Housing*Implantation*Parity	2	2	2	2	2	2
Housing* Familiarity*Parity	2	2	2	2	2	2
Implantation*Familiarity*Parity	2	2	2	2	2	2
Group(House*Implantation*Familiarity*Parity)[b]	68	68	68	68	68	68
Time Sub-Plot						
Time		3	5	2	1	3
House*Time		3	5	2	1	3
Implantation*Time		3	5	2	1	3
Familiarity*Time		3	5	2	1	3
Parity*Time		6	10	4	2	6
House*Implantation*Time		3	5	2	1	3
House*Familiarity*Time		3	5	2	1	3
House*Parity*Time		6	10	4	2	6
Implantation*Familiarity*Time		3	5	2	1	3
Implantation*Parity*Time		6	10	4	2	6
Familiarity*Parity*Time		6	10	4	2	6
Group(House*Implantation*Familiarity*Parity*Time)[c]		243	405	162	81	243

[a] Main Plot Error Term
[b] Treatment Sub-plot error term
[c] Time Sub-plot error term

Table 3.3 (continued)

Variable Tested	Degrees of Freedom					
Time of Day Sub-Plot	A	B	C	D	E	F
Time of Day						2
House*Time of Day						2
Implantation*Time of Day						2
Familiarity*Time of Day						2
Parity*Time of Day						4
Time*Time of Day						6
House*Implantation*Time of Day						2
House*Familiarity*Time of Day						2
House*Parity*Time of Day						4
House*Time*Time of Day						6
Implantation*Familiarity*Time of Day						2
Implantation*Parity*Time of Day						4
Familiarity*Parity*Time of Day						4
Implantation*Time*Time of Day						6
Familiarity*Time*Time of Day						6
Parity*Time*Time of Day						12
Group(House*Implantation*Familiarity*Parity*Time*Time of Day)[d]						672

[d] Time of Day Sub-plot error term

3.3. Results

3.3.1. Aggression Post-Mixing

Housing did not have a significant effect on the number of aggressive encounters and the average duration of aggressive encounters post-mixing (Table 3.4). The total duration of aggressive encounters tended to be longer in the static pens than in the dynamic housing system (p=0.09; Table 3.4).

Stage of gestation did not have a significant effect on the number of aggressive encounters nor the total and average duration of aggressive encounters that occurred post-mixing (Table 3.4). The average duration and number of aggressive encounters were not affected by familiarity. There was a tendency for the total duration of aggressive encounters to be longer for sows that were familiar with their group mates than those that were unfamiliar (p=0.09; Table 3.5).

Parity significantly affected the total duration (p=0.02) and the number of aggressive encounters (p=0.04; Table 3.5) that occurred post-mixing. Old sows were involved in more aggressive encounters at mixing. The total duration of aggressive encounters involving old sows was longer than the duration aggressive encounters that involved young or intermediate sows. Parity did not have an affect on the average duration of aggressive encounters post-mixing (Table 3.5).

There was a significant interaction between housing and familiarity on the total (p=0.03) and average (p=0.07) duration of aggressive encounters post-mixing (Figure 3.4). The familiar sows housed in the static pens spent more time fighting.

3.3.2. Aggression at the Feeder

There was not a significant effect of housing, familiarity or parity on the number of aggressive encounters initiated or received at the feeder (Tables 3.4 and 3.5). The sows' stage of gestation at mixing did not have an affect on the number of aggressive

63

Table 3.4 The effect of housing and stage of gestation on aggression at mixing and at the feeder, injury scores, body weight, lameness, feeder entry order, salivary cortisol concentrations, lying patterns, time standing and farrowing productivity in sows housed in an Electronic Sow Feeding system.

Parameter Examined	Housing				Stage of Gestation			
	Static	Dynamic	SE	p-value	Pre-implant	Post-implant	SE	p-value
Aggression Post-Mixing								
# of Encounters (per sow/ 4h)	3.72	2.55	0.57	0.2	3.19	3.08	0.49	0.9
Total Duration of Aggressive Encounters (sec)	91.6	41.7	17.7	0.09	77.0	56.3	15.0	0.6
Average Duration of Aggressive Encounters (sec)	16.4	9.6	2.4	0.1	14.7	11.4	2.1	0.9
Aggression at Feeder (#/sow/15h)								
Initiated	0.72	0.85	0.15	0.6	0.97	0.60	0.13	0.01
Received	0.76	0.83	0.15	0.5	0.96	0.64	0.15	0.1
Injury Scores (#/sow)								
Scratch Score	3.64	3.81	0.10	0.8	3.75	3.70	0.10	0.7
Other Injuries	1.96	1.58	0.16	0.2	1.71	1.83	0.14	0.6
Total Injury Score	5.60	5.40	0.18	0.4	5.46	5.53	0.18	0.7
Body Weight (kg)	267.3	263.4	3.2	0.4	263.1	267.7	2.9	0.2
Lameness (0 to 2; 0 = not lame)	0.036	0.045	0.013	0.9	0.041	0.040	0.011	0.3
Feeder Entry Order (0 to 1)*	0.518	0.524	0.023	0.8	0.498	0.544	0.023	0.1
Salivary Cortisol (ng/mL)	7.49	9.64	0.71	0.1	7.65	9.48	0.61	0.0008
Lying Patterns (Proportion of observations, %)								
Solid: wall	31.6	24.8	2.5	0.1	30.9	26.0	2.5	0.1
Solid: centre	45.9	50.6	4.3	0.4	51.2	45.3	3.3	0.2
Slat	21.1	24.3	4.3	0.6	16.7	28.7	3.9	0.001
Standing (Proportion of observations, %)	14.3	11.4	2.7	0.4	13.2	12.5	2.1	0.7
Farrowing Productivity								
Farrowing Rate (%)	83.1	89.1		>0.05	83.6	89.9		>0.05
Total Born (piglets/litter)	12.95	12.07	0.46	0.8	11.99	12.43	0.10	0.4
Born Alive (piglets/litter)	10.96	10.87	0.38	0.8	10.57	11.26	0.35	0.2

* Zero was assigned to first sow that entered the feeder and 1 was assigned to the last sow that entered the feeder.

Table 3.5 The effect of familiarity and parity on aggression at mixing and at the feeder, injury scores, body weight, lameness, feeder entry order, salivary cortisol concentrations, lying patterns, time standing and farrowing productivity in sows housed in an Electronic Sow Feeding system.

Parameter Examined	Familiarity				Parity				
	Familiar	Unfamiliar	SE	p-value	Young	Intermediate	Old	SE	p-value
Aggression Post-Mixing									
# of Encounters (per sow/ 4h)	3.28	3.00	0.49	0.2	2.39[b]	2.42[b]	4.60[a]	0.56	0.04
Total Duration of Aggressive Encounters (sec)	77.5	55.8	14.9	0.09	37.7[b]	48.8[b]	113.5[a]	17.0	0.02
Average Duration of Aggressive Encounters (sec)	15.5	10.5	2.1	0.1	12.6	11.1	15.4	2.4	0.5
Aggression at Feeder (#/sow/15h)									
Initiated	0.81	0.76	0.13	0.2	0.71	0.90	0.74	0.15	0.7
Received	0.91	0.69	0.13	0.1	0.84	0.92	0.63	0.14	0.3
Injury Scores (#/sow)									
Scratch Score	3.68	3.77	0.10	0.2	4.01[a]	3.61[b]	3.55[b]	0.12	0.07
Other Injuries	1.94	1.60	0.15	0.09	1.70	1.91	1.70	0.17	0.6
Total Injury Score	5.62	5.37	0.18	0.3	5.71	5.53	5.25	0.21	0.3
Body Weight (kg)	268.0	262.8	2.9	0.2	222.9	268.0	305.4	3.5	<0.001
Lameness (0 to 2; 0 = not lame)	0.042	0.039	0.013	0.4	0.044	0.043	0.034	0.013	0.9
Feeder Entry Order (0 to 1)*	0.535	0.507	0.023	0.03	0.644[a]	0.477[b]	0.445[b]	0.028	<0.001
Salivary Cortisol (ng/mL)	8.40	8.72	0.62	0.9	9.08[a]	7.46[b]	9.15[a]	0.71	0.003
Lying Patterns (Proportion of observations, %)									
Solid: wall	32.1	24.4	2.5	0.03	19.2[b]	21.3[b]	44.2[a]	3.0	<0.001
Solid: centre	43.0	53.3	3.8	0.02	46.7	53.5	44.6	4.4	0.2
Slat	23.9	21.5	3.5	0.5	33.1[a]	24.1[b]	10.9[c]	4.0	<0.001
Standing (Proportion of observations, %)	12.4	13.3	2.1	0.6	14.2	13.2	11.2	2.4	0.4
Farrowing Productivity									
Farrowing Rate (%)	87.3	85.2		>0.05	83.8	88.2	86.1		>0.05
Total Born (piglets/litter)	12.43	11.73	0.39	0.7	11.78	12.56	11.90	0.45	0.2
Born Alive (piglets/litter)	11.20	10.63	0.35	0.1	10.78	11.37	10.60	0.40	0.3

* Zero was assigned to first sow that entered the feeder and 1 was assigned to the last sow that entered the feeder.
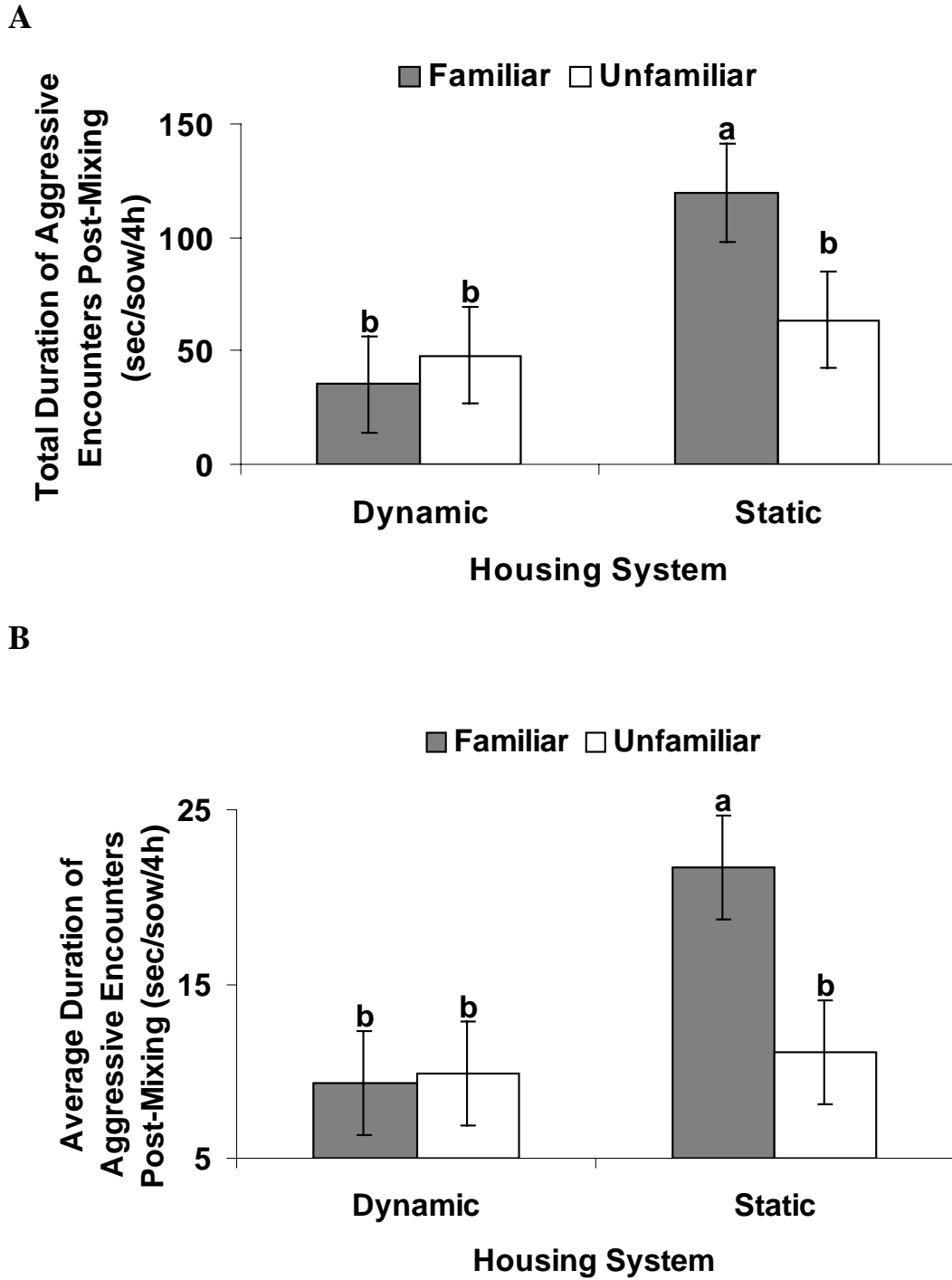Means lacking or without a common superscript differ (P<0.05).

A

B

Figure 3.4   The interaction between housing and familiarity on the total ($p = 0.03$; A) and average ($p = 0.07$; B) duration of aggressive encounters that occurred post-mixing among sows in an Electronic Sow Feeding system. Means without a common superscript differ ($p < 0.05$).

encounters received at the feeder (Table 3.4). However, it did affect the number of aggressive encounters initiated at the feeder (p=0.01; Table 3.4). Sows that were mixed pre-implantation initiated more aggressive encounters at the feeder than sows that were mixed post-implantation.

The time of day affected the level of aggression at the Electronic Sow Feeding station. As illustrated in Table 3.6, significantly fewer aggressive encounters were initiated (p<0.001) and received (p<0.001) during period 3 (23:00 to 06:00 h) than during the two earlier periods (15:00 to 23:00 h).

There was a significant interaction between housing and the time of day on the number of aggressive encounters initiated (p=0.002) and received (p=0.0006) at the feeder. As seen in Figure 3.5, after the feeder reset, the high levels of aggression persisted longer in the dynamic system than in the static pens.

There was a significant interaction between parity and the time of day on the number of aggressive interactions initiated (p<0.001) and received (p<0.001) at the feeder entrance (Figure 3.6). Compared with intermediate and older sows, young sows were involved in fewer interactions in the first period (15:00 to 19:00 h), similar levels in the second period (19:00 to 23:00 h) and more interactions in the third observation period (23:00 to 06:00 h).

There was a significant three-way interaction between stage of gestation, familiarity and time of day on the number of aggressive interactions initiated (p=0.01) and received (p=0.03) at the feeder (Figure 3.7). The familiar pre-implant sows were involved in relatively more interactions during the first two periods (15:00 to 23:00 h) than the other treatment combinations.

The number of days post-mixing affected the number of aggressive encounters initiated (p<0.001) and received (p<0.001; Table 3.7) at the feeder. Aggression levels at the feeder were higher later in gestation (weeks 3 and 8 post-mixing).

There was a significant interaction between time of day and days post-mixing on the number of aggressive encounters initiated (p<0.001) and received (p<0.001) at the feeder (Figure 3.8). The time of day differences previously mentioned were not evident until later in gestation (days 28 and 63 post-mixing).

Table 3.6 The number of aggressive encounters initiated and received by the sows at the Electronic Sow Feeding station entrance for each time period after the feeder reset.

Number of Aggressive Encounters (#/sow/period)	Time of Day (h)			SE	p-value
	15:00 - 19:00	19:00 - 23:00	23:00 - 06:00		
Initiated	1.09^a	0.95^a	0.31^b	0.13	<0.001
Received	1.02^a	1.02^a	0.34^b	0.13	<0.001

[a, b] Means lacking a common superscript (same row) are different at p<0.05.

A
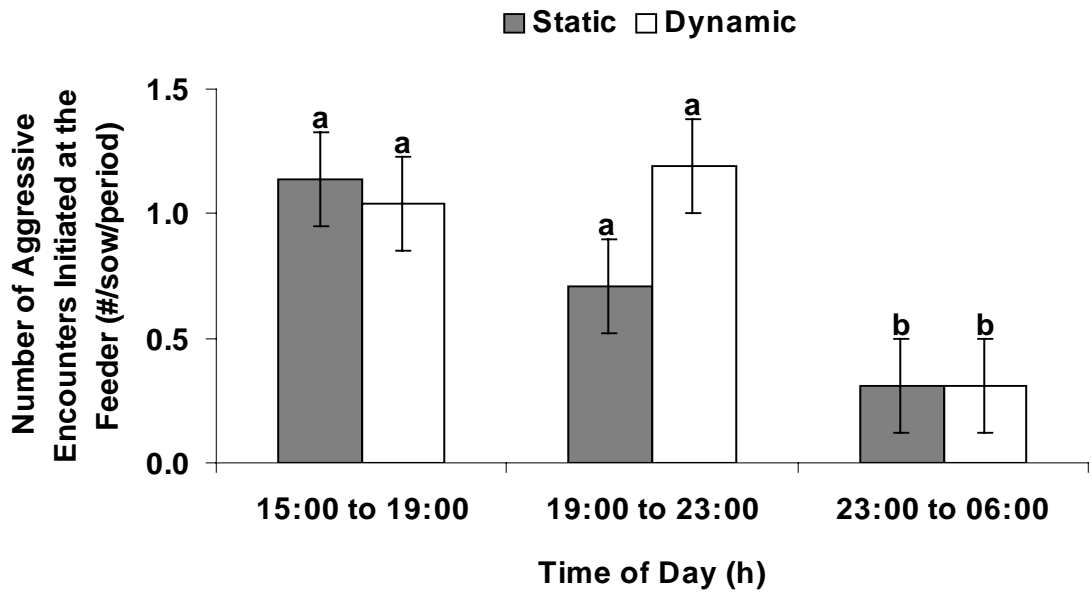
B
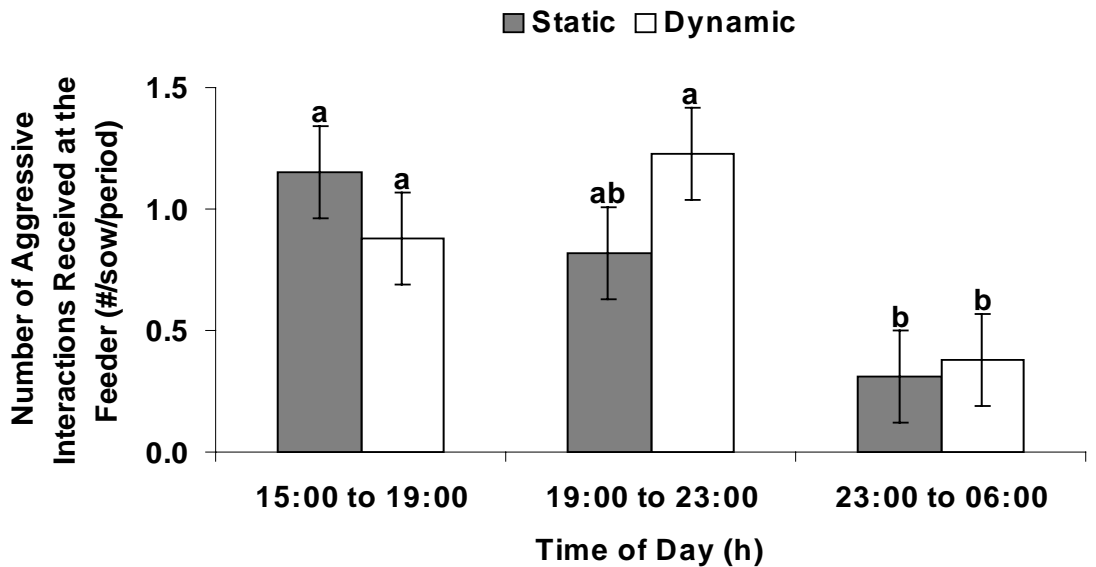
Figure 3.5   The interaction between housing and time period on the number of aggressive interactions initiated (p=0.002; A) and received (p=0.0006; B) by the sows at the Electronic Sow Feeding station entrance after the feeder reset. Means without a common superscript differ (p<0.05).

A
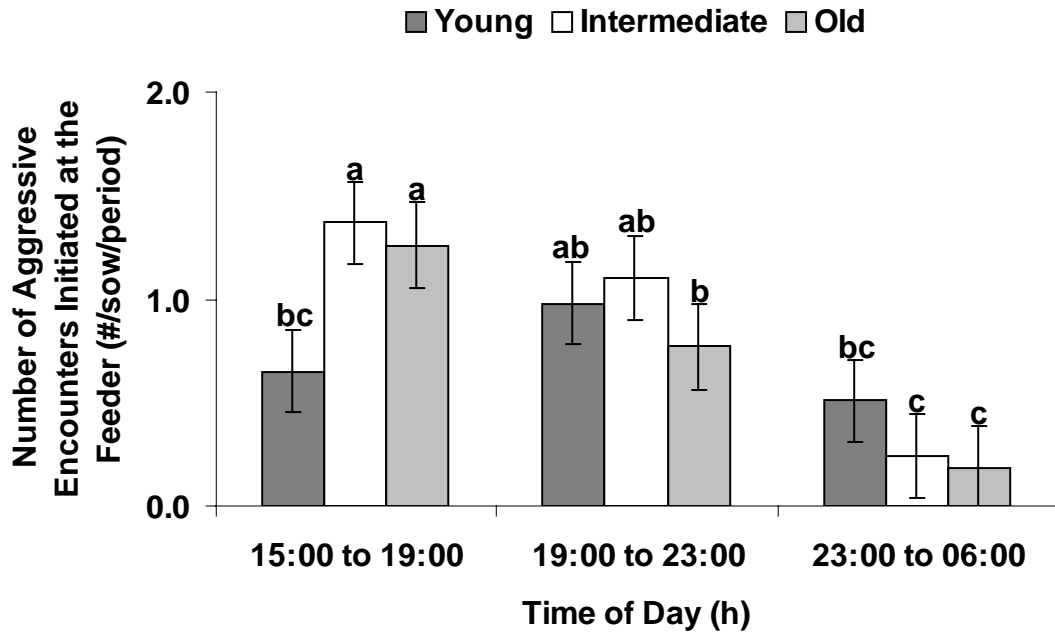
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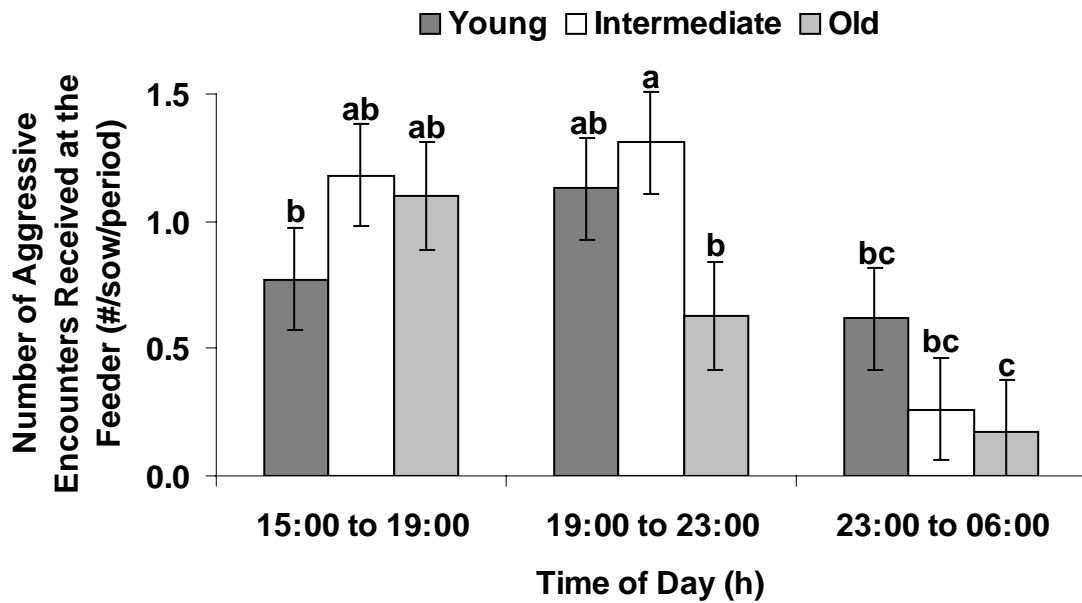
Figure 3.6   The interaction between parity and time period on the number of aggressive encounters initiated (p<0.001; A) and received (p<0.001; B) by the sows at the Electronic Sow Feeding station entrance after the feeder resets. Means without a common superscript differ (p<0.05).

A
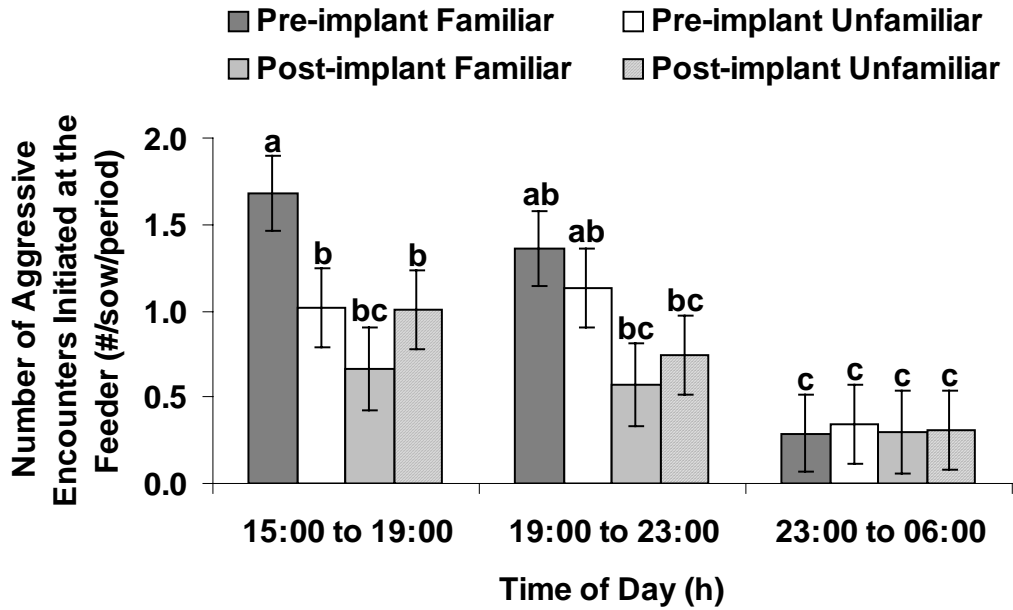
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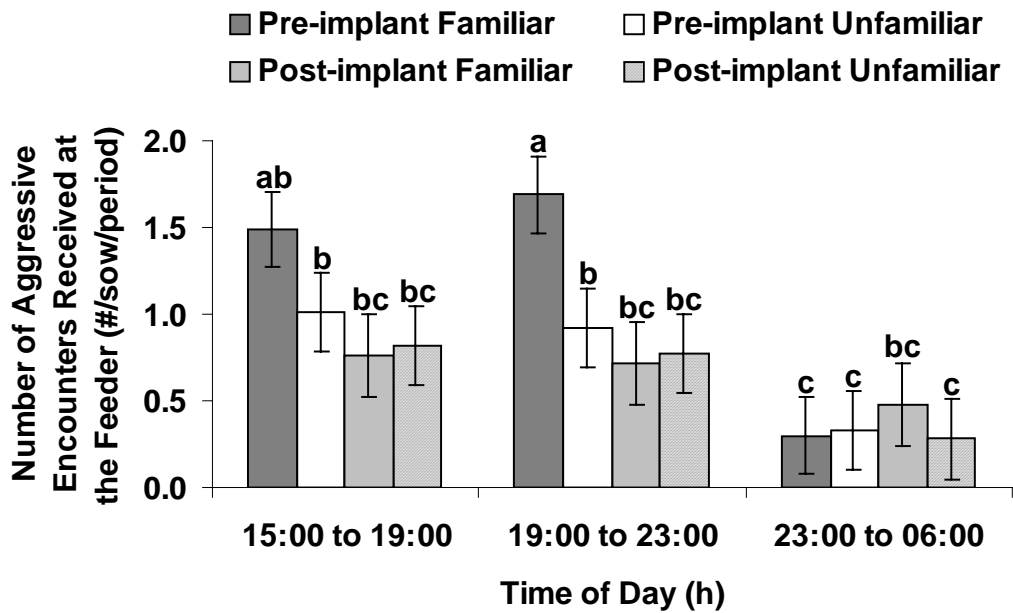
Figure 3.7 The three-way interaction between stage of gestation, familiarity and time period on the number of aggressive interactions initiated ($p=0.01$; A) and received ($p=0.03$; B) by the sows at the entrance of Electronic Sow Feeding station after the feeder reset. Means without a common superscript differ ($p<0.05$).

Table 3.7 The number of aggressive encounters initiated and received by the sows at the entrance of the Electronic Sow Feeding station based on the number of days post-mixing

Number of Aggressive Encounters (#/sow/15h)	Days Post-Mixing				SE	p-value
	1	3	28	63		
Initiated	0.11^b	0.41^b	1.12^a	1.18^a	0.15	<0.001
Received	0.15^b	0.42^b	1.45^a	1.17^a	0.15	<0.001

[a, b] Means lacking a common superscript (same row) are different at p<0.05.

A
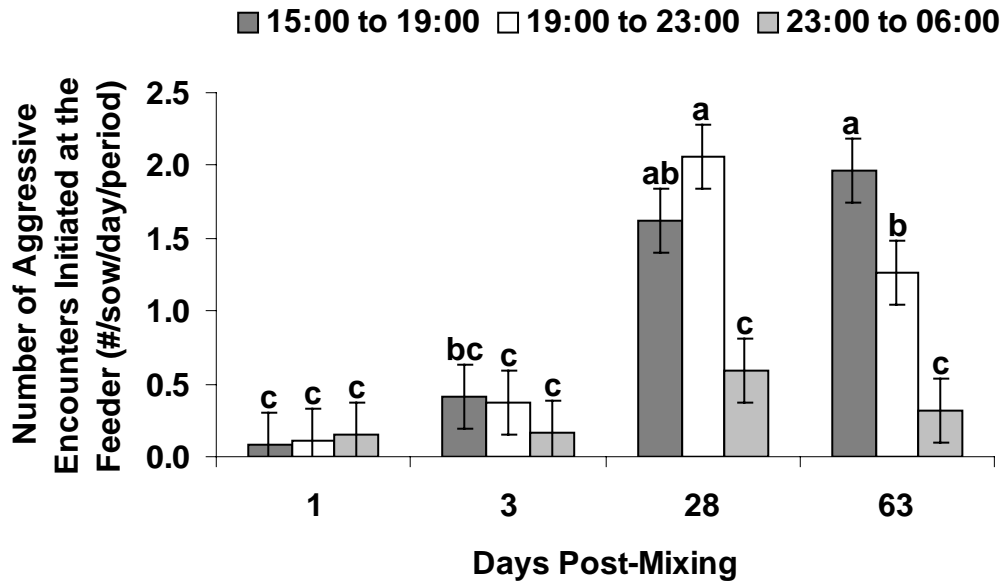
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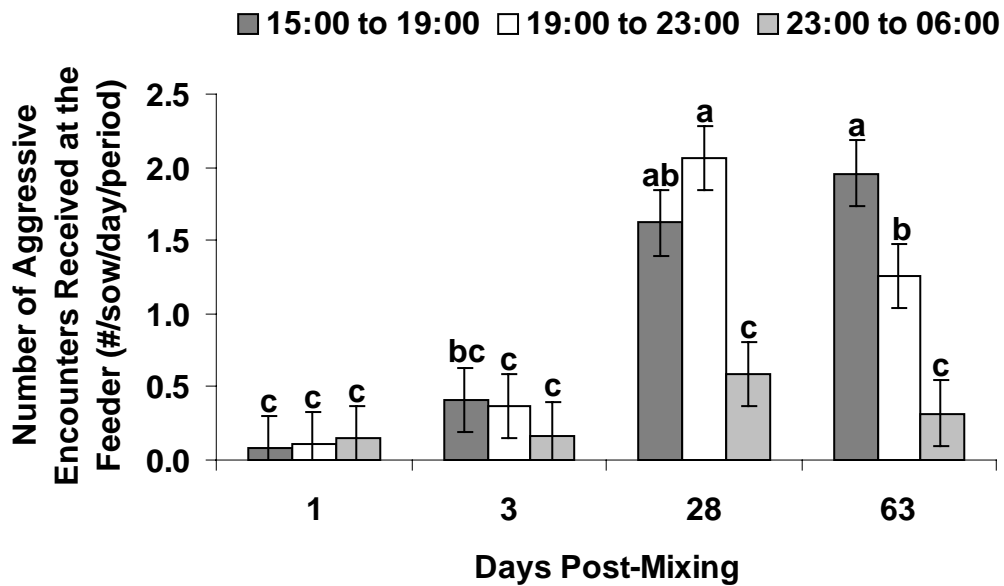
Figure 3.8   The interaction between time period and days post-mixing on the number of aggressive interactions initiated ($p<0.001$; A) and received ($p<0.001$; B) by the sows at the entrance of the Electronic Sow Feeding station after the feeder reset. Means without a common superscript differ ($p<0.05$).

There was also a significant interaction between stage of gestation and days post-mixing on the number of aggressive encounters initiated (p=0.02; Figure 3.9). Sows mixed pre-implantation initiated significantly more aggressive interaction on day 28 post-mixing.

3.3.3. Injury Scores

The lameness scores were not affected by housing, stage of gestation, familiarity or parity (Tables 3.4 and 3.5). The amount of time that has elapsed since mixing significantly affected the sows' lameness score. The sows had a significantly higher lameness score when they were in group housing than when they were in stalls or farrowing (Table 3.8; p<0.001).

Housing, stage of gestation and familiarity did not have a significant effect on the sows' body weights (Tables 3.4 and 3.5). Parity significantly affected body weight (p<0.001; Table 3.5). Young and intermediate sows weighed less than old sows. The sows' average body weight at farrowing (288.5 ± 2.7 kg) was heavier than the body weight at mixing (242.2 ± 2.6 kg; p<0.001).

3.3.3.1. Scratch Score

Housing, stage of gestation and familiarity did not have a significant effect on the scratch score (Tables 3.4 and 3.5). There was a tendency for young sows to have a higher scratch score than intermediate and old sows (p=0.07; Table 3.5).
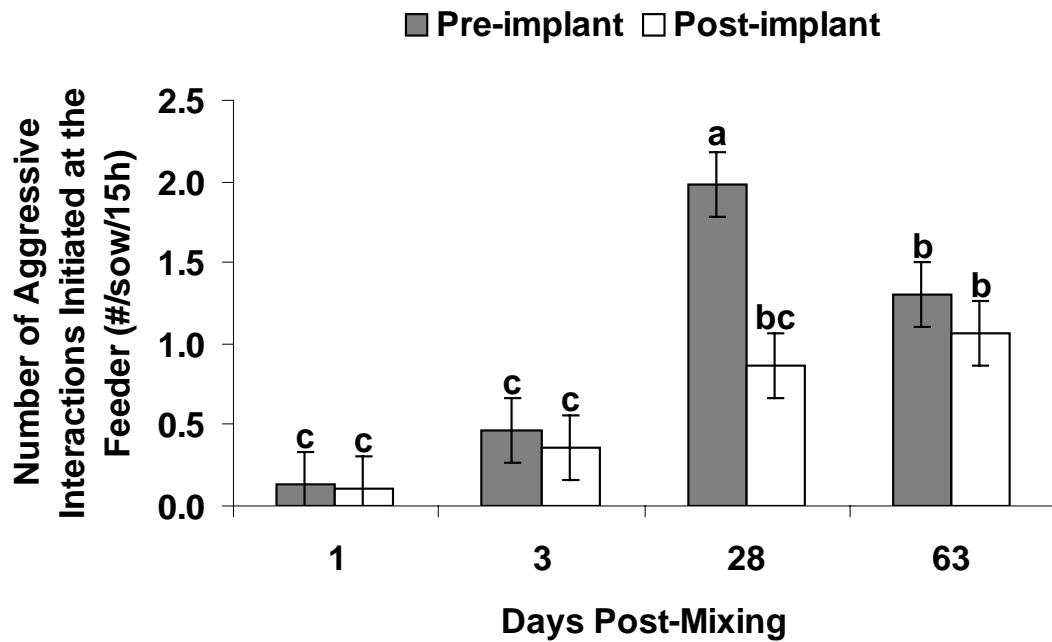
Figure 3.9   The interaction between stage of gestation and days post-mixing on the number of aggressive encounters initiated (p=0.02) by the sows at the Electronic Sow Feeding station entrance after the feeder reset. Means without a common superscript differ (p<0.05).

**Table 3.8**   The changes in the lameness score of sows housed in an Electronic Sow Feeding system throughout gestation.

| | Days Post-Mixing | | | | | | SE | p-value |
	0	3	28	63	Farrow	Lactation		
Lameness Score	0.001^b	0.072^a	0.062^a	0.063^a	0.044^{ab}	0.001^b	0.017	<0.001

The number of days post-mixing affected the number of scratches present on a sow (p<0.001; Table 3.9). The lowest score was taken before mixing (day 0). The highest scratch scores were recorded on days 3, 28 and 63 post-mixing. The next highest value was recorded at farrowing, although this value did not differ significantly from the scratch score recorded on day 63. The scratch score recorded during lactation was lower than the farrowing score but higher than the pre-mixing (day 0) score.

There was a significant interaction between housing and day post-mixing on the scratch score (p=0.02; Figure 3.10), with higher scratch scores persisting longer in the dynamic treatment.

3.3.3.2. Other Injury Score

There was not a significant effect of housing, stage of gestation or parity on the other injury score (Tables 3.4 and 3.5). There was a tendency for the familiar sows to have a higher other injury score than the unfamiliar sows (p=0.09; Table 3.5).

The number of days post-mixing significantly affected the magnitude of the other injury score (p<0.001; Table 3.9). The highest other injury scores were observed 28 and 63 days post-mixing. The lowest other injury scores were seen during farrowing and lactation and moderate values were seen on days 0 and 3 post-mixing. The other injury score for day 3 was less than the scores on days 28 and 63, but was greater than the day 0 score. The day 0 score was greater than the farrowing and lactation scores.

There was a significant interaction between stage of gestation and the number of days post-mixing on the other injury score (p=0.04; Figure 3.11). The other injury score of post-implantation sows was significantly higher before mixing (day 0) than the score taken during lactation.

Table 3.9   The changes in the scratch, other and total injury scores on sows housed in an Electronic Sow Feeding station throughout the gestation cycle.

Injury Score (#/sow)	Days Post-Mixing						SE	p-value
	0	3	28	63	Farrow	Lactation		
Scratch*	1.11^d	4.87^a	5.11^a	4.44^{ab}	4.36^b	2.46^c	0.13	<0.001
Other**	1.44^c	2.18^b	2.63^a	2.83^a	0.72^d	0.82^d	0.16	<0.001
Total***	2.55^e	7.05^b	7.75^a	7.27^{ab}	5.08^c	3.29^d	0.20	<0.001

[a, b, c, d, e] Means lacking a common superscript (same row) are different at p<0.05.

* A score of zero means that there were no scratches on the two regions of the body scored.

** The score for swellings, cuts and abscesses on 18 regions of the body, zero means the there were no swellings, cuts or abscesses.

*** The sum of scratch and other injury scores. A score of zero means there were no injuries.

Figure 3.10 The interaction between housing and days post-mixing on the scratch score on sows housed in an Electronic Sow Feeding system (p=0.02). Means without a common superscript differ (p<0.05).

Figure 3.11   The interaction between stage of gestation at mixing and days post-mixing on the other injury score of sows housed in an Electronic Sow Feeding system (p=0.04). Means without a common superscript differ (p<0.05).

3.3.3.3. Total Injury Score

Housing, stage of gestation, familiarity and parity did not have a significant effect on the total injury score (Tables 3.4 and 3.5). However, there was a significant interaction between the stage of gestation and familiarity on the total injury score (p=0.03). As illustrated in Figure 3.12, familiar sows mixed post-implantation had a higher total injury score than unfamiliar sows mixed post-implantation.

The total injury score was affected by the number of days that had elapsed since mixing (p<0.001; Table 3.9). The lowest total injury score was taken before mixing (day 0). The highest total injury scores occurred 28 and 63 days post-mixing, which was when the scratch and other injury scores were both at their peaks. The next highest score was taken on day 3, which was not significantly different from the score taken on day 63. The score taken at farrowing was significantly lower than the day 3 score, but was higher than the lactation score. The lactation score was the second lowest total injury score, after the pre-mixing (day 0) score.

There was a significant interaction between housing and days post-mixing on the total injury score (p=0.03; Figure 3.13). The total injury score of static sows taken 28 days post-mixing was higher than the scores taken on days 3 and 63 for the sows in the dynamic housing system.

There was a significant interaction between the stage of gestation and the number of days post-mixing on the total injury score (p=0.003; Figure 3.14). Sows mixed post-implantation had a higher total injury score at farrowing than the sows mixed pre-implantation.

3.3.4. Feeder Entry Order

Housing, stage of gestation and familiarity did not have a significant effect on the feeder entry order (Tables 3.4 and 3.5). Parity significantly affected the feeder entry order (p<0.001; Table 3.5), as young sows ate significantly later in the feeding cycle than both intermediate and older sows.
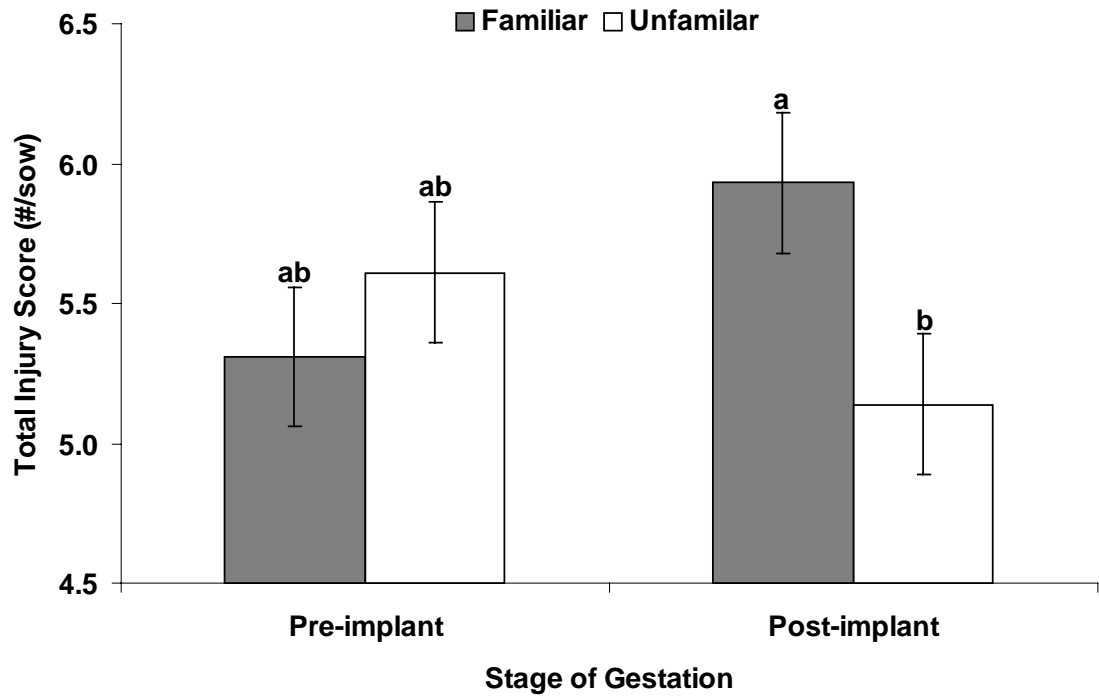
Figure 3.12 The interaction between familiarity and stage of gestation on the total injury scores of the sows housed in an Electronic Sow Feeding system (p=0.03). Means without a common superscript differ (p<0.05).
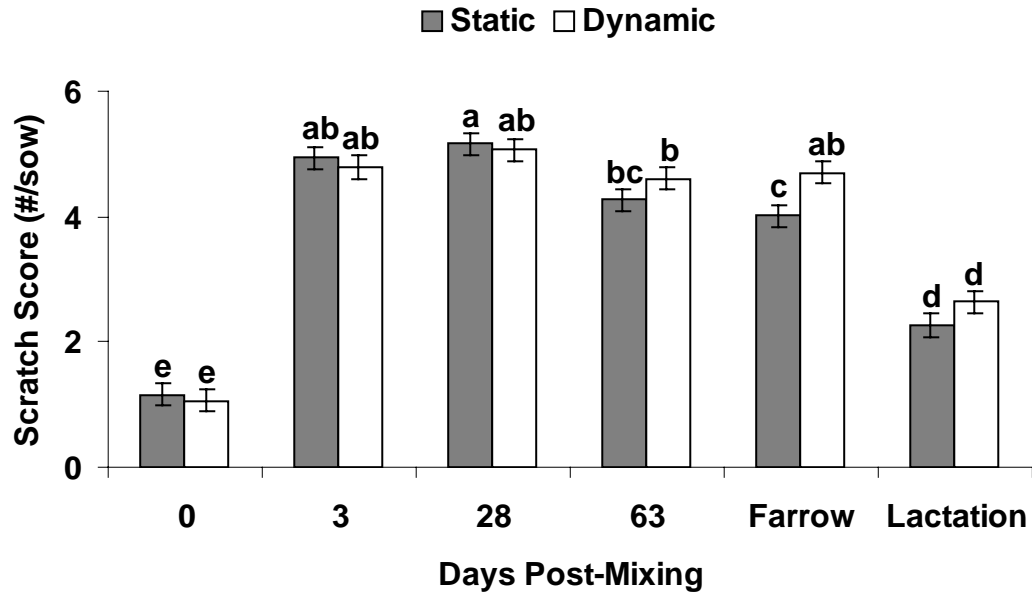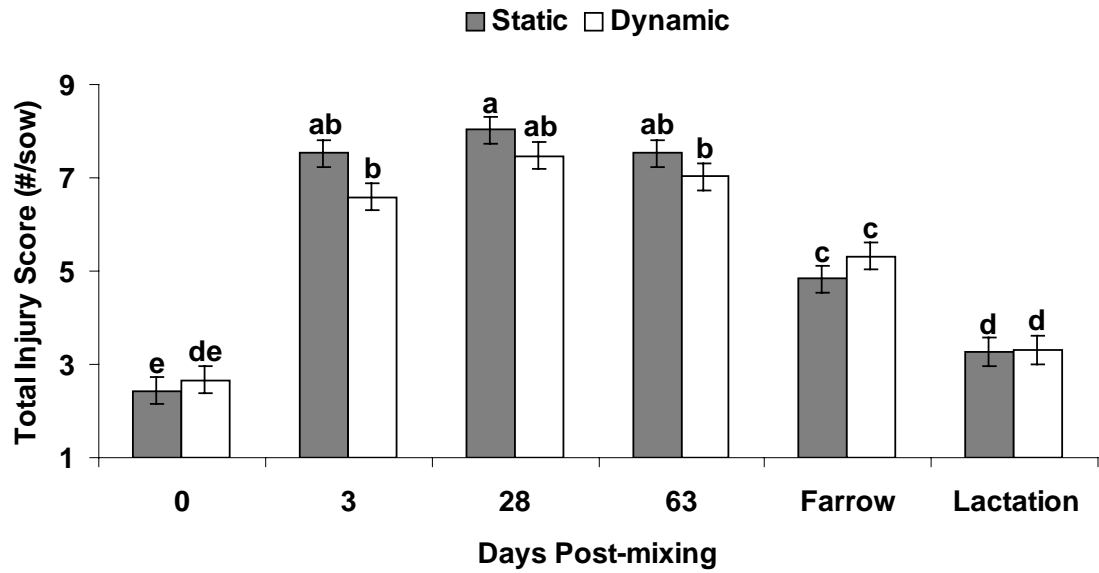
Figure 3.13 The interaction between housing and days post-mixing on the total injury scores of sows housed in an Electronic Sow Feeding system. Means without a common superscript differ ($p<0.05$).
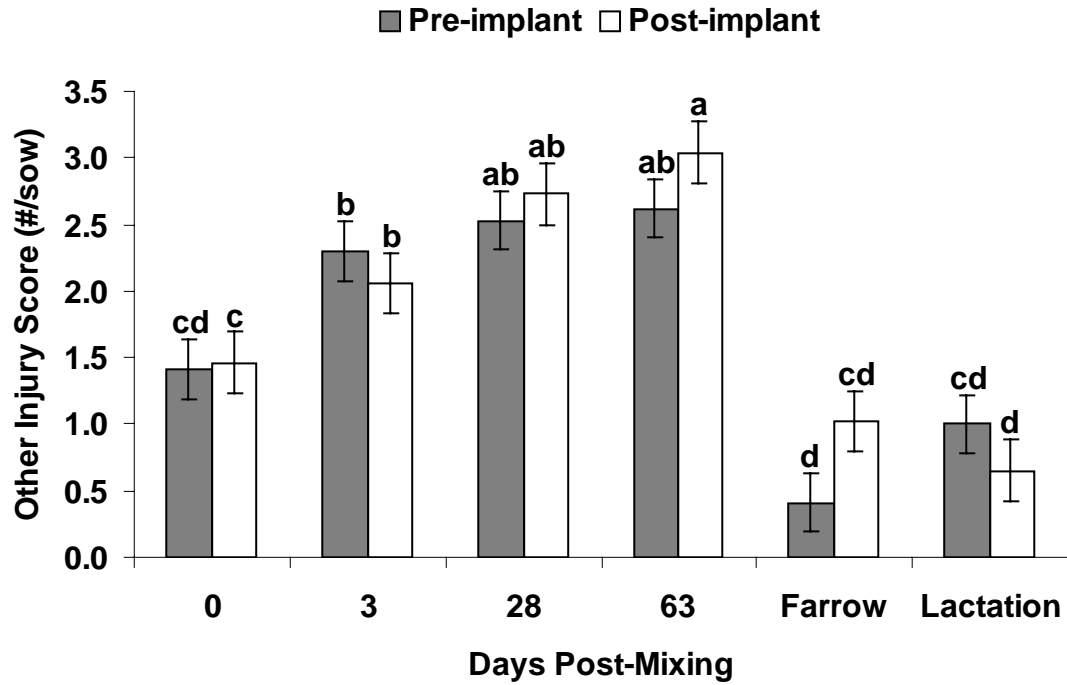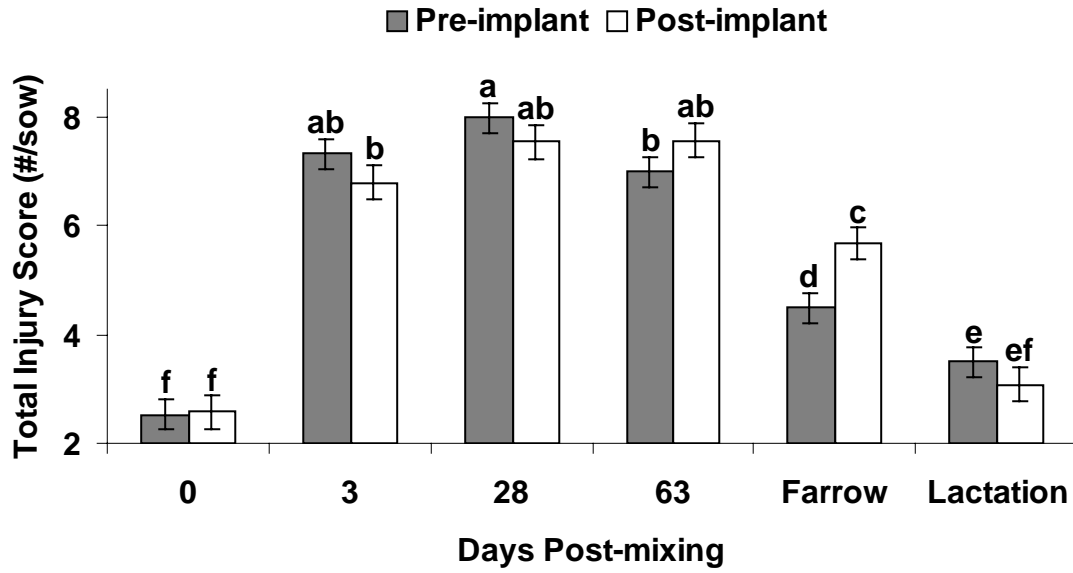
Figure 3.14   The interaction between stage of gestation and days post-mixing on the total injury score of sows housed in an Electronic Sow Feeding system (p=0.003). Means without a common superscript differ (p<0.05).

As seen in Figure 3.15, there was a significant interaction between the stage of gestation and the days post-mixing (p=0.03) on the feeder entry order. Post-implant sows ate significantly later than pre-implant sows on days 3 and 28 post-mixing.

3.3.5. Salivary Cortisol

Salivary cortisol concentrations were not significantly affected by housing and familiarity (Tables 3.4 and 3.5). Sows mixed post-implantation had significantly higher cortisol concentrations than their pre-implant counterparts (p=0.0008; Table 3.4). There were significant differences in salivary cortisol concentrations based on parity (p=0.003; Table 3.5). Intermediate sows had lower cortisol concentrations than the young and old sows.

The number of days post-mixing affected salivary cortisol concentrations (p<0.001; Table 3.10). Pre-mixing values (day 0) were significantly lower than all the post-mixing values. The cortisol concentrations on days 1 and 2 post-mixing were not significantly different. The cortisol concentration of day 3 post-mixing was higher than the day 1 post-mixing concentration, but was not different from the day 2 values. The day 28 and 63 post-mixing concentrations were not different but were higher than the day 3 post-mixing value.

There was an interaction between housing system and days post-mixing on the cortisol concentrations (p=0.0006). As illustrated in Figure 3.16, on days 28 post-mixing, the cortisol concentrations of the sows housed in the dynamic system were higher than the concentrations of sows housed in static pens.

3.3.6. Lying Patterns

Housing did not significantly affect the amount of time sows spent standing or lying in a particular area of the pen (Table 3.4). The stage of gestation affected the percentage of time sows spent lying on the slats (p=0.001; Table 3.4). The sows that
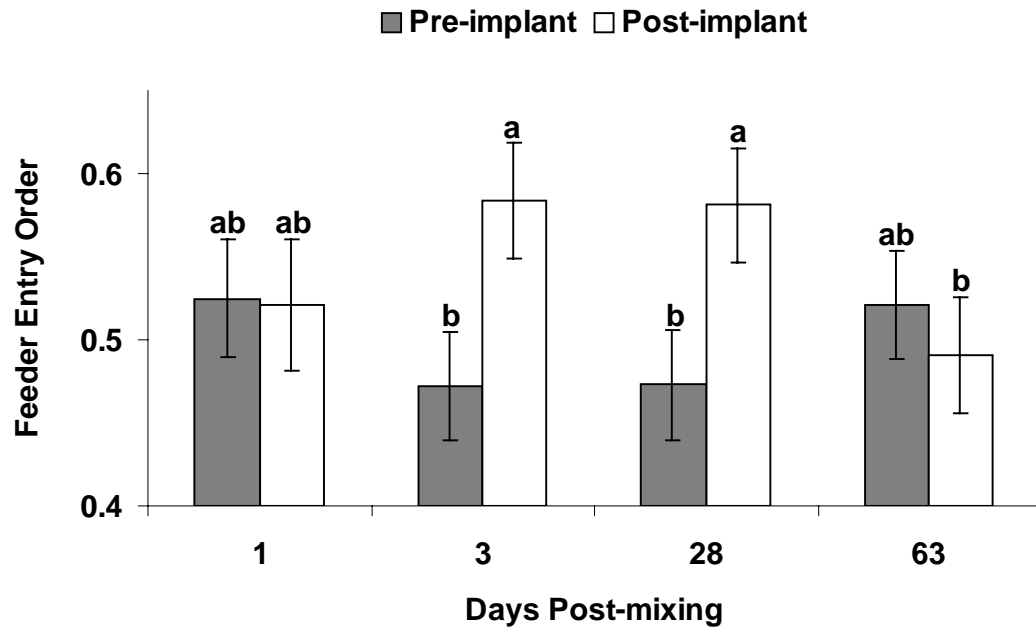
Figure 3.15 Interaction between stage of gestation and days post-mixing on the feeder entry order of sows housed in an Electronic Sow Feeding system (p=0.03). The lower the score, the earlier the sows ate (The closer the score is to zero, the earlier that the sows ate). Means without a common superscript differ (p<0.05).

Table 3.10   The changes in salivary cortisol concentrations of sows housed in an Electronic Sow Feeding system throughout gestation.

	Days post-mixing						SE	p-value
	0	1	2	3	28	63		
Mean cortisol concentration (ng/mL)	1.59^d	7.35^c	8.65^{bc}	9.36^b	11.82^a	12.61^a	0.80	<0.001

[a, b, c, d] Means lacking a common superscript are different at p<0.05.
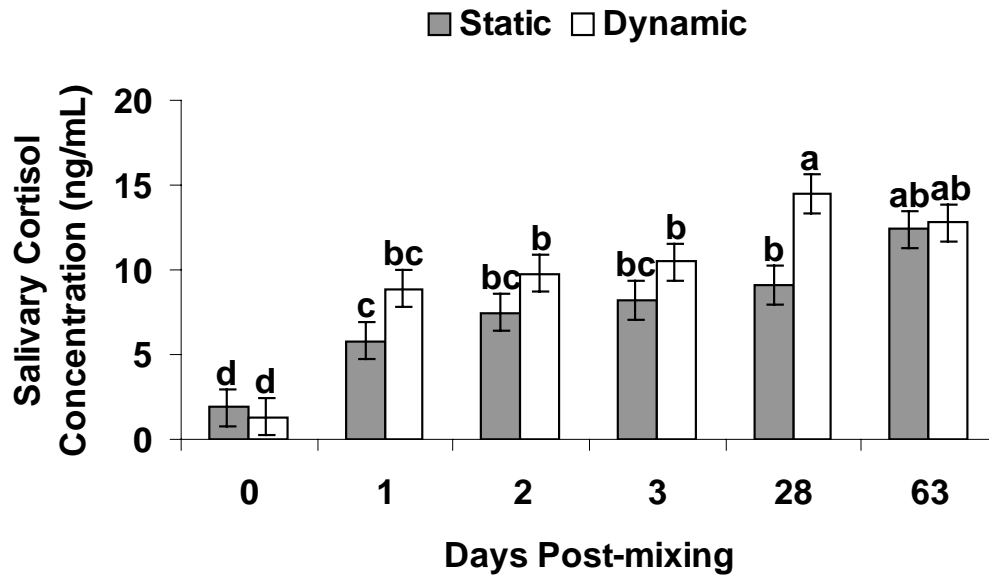
Figure 3.16 The interaction between housing and days post-mixing on the salivary cortisol concentrations of sows housed in an Electronic Sow Feeding system (p=0.0006). Means without a common superscript differ (p<0.05).

were mixed post-implantation spent significantly more time lying on the slats than the sows that were mixed pre-implantation. Stage of gestation did not affect the percentage of time the sows spent lying in the solid areas of the pen (center and against the wall) or standing (Table 3.4).

Familiarity affected the percentage of time the sows spent lying against the wall (p=0.03) and in the center in the solid area of the pen (p=0.02; Table 3.5). Familiar sows spent a greater percentage of their time lying against the wall in the solid portion of the pen, while unfamiliar sows spent a greater proportion of their time lying in the centre of the solid area of the pen. Familiarity did not significantly affect the percentage of time the sows spent standing or lying on the slats (Table 3.5).

Parity affected the percentage of time the sows spent lying against the wall in the solid area of the pen (p<0.001), and lying on the slats (p<0.001; Table 3.5). Old sows spent a higher percentage of their time lying against the wall and the lowest proportion of their time lying on the slats, compared with intermediate and young sows. There was no difference in the percentage of time young and intermediate sows spent lying against the wall in the solid area of the pen. However, young sows spent a significantly higher percentage of their time lying on the slats than intermediate sows.

The number of weeks post-mixing created variation in the percentage of time sows spent standing or lying in each of the areas of the pen (Table 3.11). The amount of time sows laid against the wall in the solid area of the pen did not change. During the week of mixing (week 0), the sows spent the lowest percentage of their time lying in the center in the solid area of the pen (p<0.001) and the highest percentage of their time lying on the slats (p<0.001) and standing (p<0.001).

There was a significant interaction between housing and weeks post-mixing on the percentage of time the sows spent lying against the wall in the solid area of the pen (p=0.03) and standing (p=0.02; Figure 3.17). During the week post-mixing, sows in static pens spent more time lying against the wall or standing than sows housed in the dynamic system.

Table 3.11   The differences in the time spent standing or lying in different locations within the pen for the number of weeks post-mixing in an Electronic Sow Feeding system.

Location in Pen	Weeks Post-mixing (Proportion of observations, %)			SE	P-Value
	0	3	8		
Solid: wall	25.2	30.1	29.4	2.6	0.2584
Solid: center	36.9[b]	53.0[a]	54.9[a]	3.8	<0.001
Slat	35.6[a]	16.8[b]	15.8[b]	3.6	<0.001
Standing	26.3[a]	7.7[b]	4.5[b]	2.3	<0.001

[a, b] Means lacking or without a common superscript (same row) are different at $p<0.05$.

A
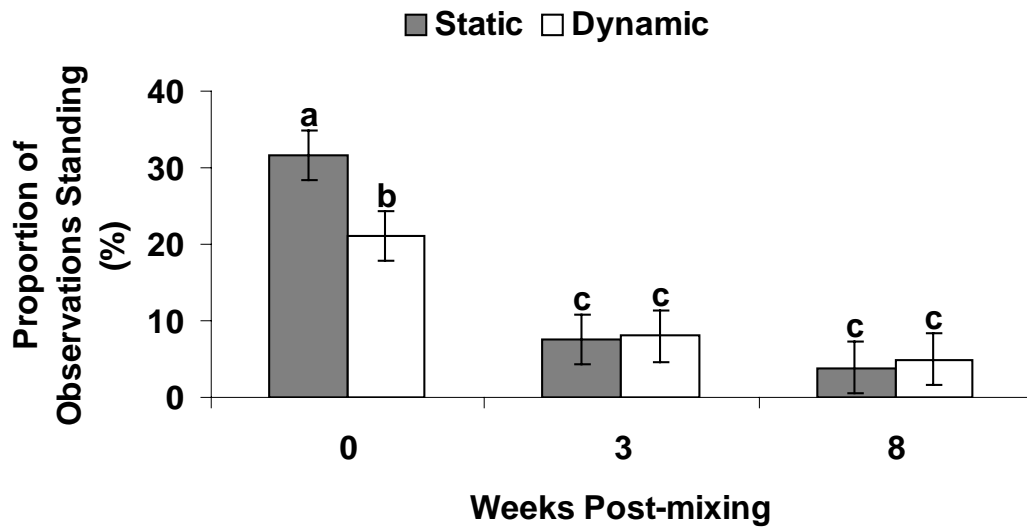
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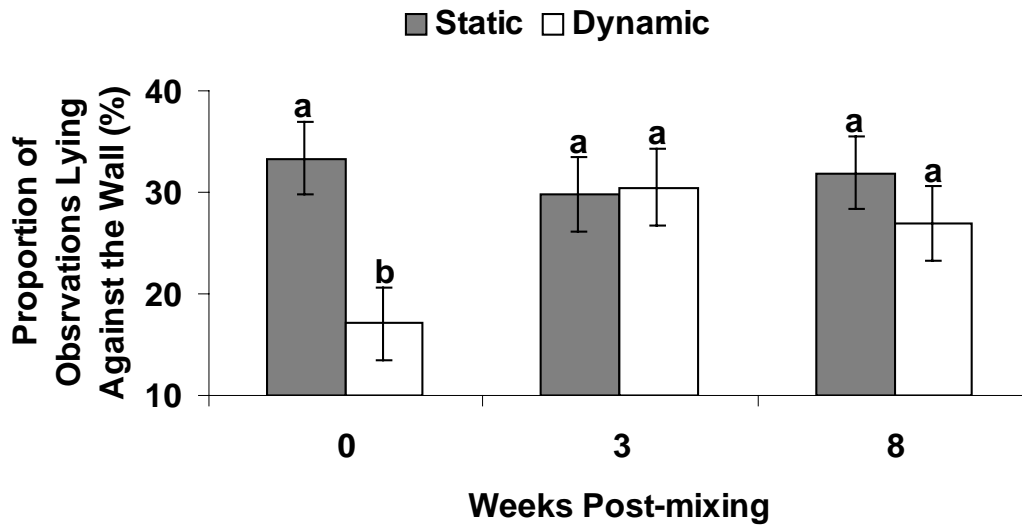
Figure 3.17   The interaction between housing and weeks post-mixing on the proportion of time sows in an Electronic Sow Feeding system spent standing (p=0.02; a) and lying against the wall (p=0.03; B). Means without a common superscript differ (p<0.05).

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There was a significant interaction between parity and weeks post-mixing on the percentage of time the sows spent lying on the slats (p=0.02; Figure 3.18). During the week of mixing, young sows spent the highest percentage of their time, old sows spent the least and the intermediate sows spent a moderate percentage of their time lying on the slats. The pattern was the same throughout gestation, but was most evident the week of mixing.

There also was a strong tendency between parity and weeks post-mixing on the percentage of time sows spent lying in the centre of the solid area of the pen (p=0.05; Figure 3.18). During the week of mixing, young sows laid in the center of the solid area of the pen less than the other age groups, but by week 8 post-mixing, there were no differences.

There was also a tendency for the amount of time the sows spent lying against the wall in the solid area of the pen to be affected by the interaction between housing and stage of gestation (p=0.06; Figure 3.19). Dynamic sows mixed post-implantation spent a lower proportion age of their time lying against the wall than the static sows mixed post-implantation, or sows mixed pre-implantation.

3.3.7. Farrowing Productivity

There were not any significant differences for housing, stage of gestation, familiarity and parity for the total number of piglets born and the number of piglets born alive (Tables 3.4 and 3.5). There was a significant interaction between housing and parity on the number of piglets born alive (p=0.03; Figure 3.20). Old sows had fewer piglets born alive when housed in static pens, and young sows had fewer piglets born alive when housed in the dynamic housing system.

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A
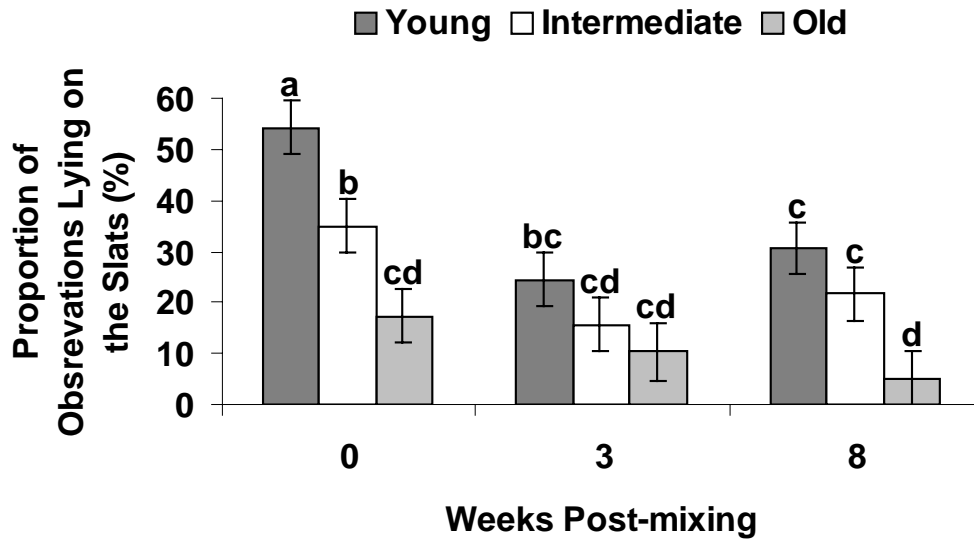
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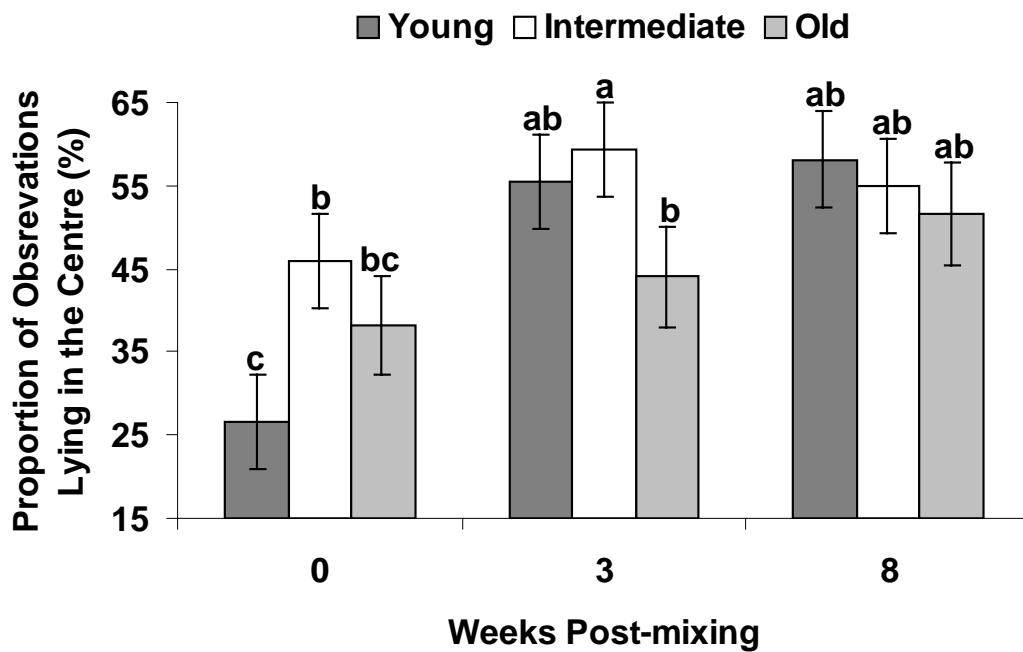
Figure 3.18   The interaction between parity and weeks post-mixing on the proportion of time sows housed in an Electronic Sow Feeding system spent lying on the slats (p= 0.02; A) and in the centre of the solid area of the pen (p=0.05; B). Means without a common superscript differ (p<0.05).
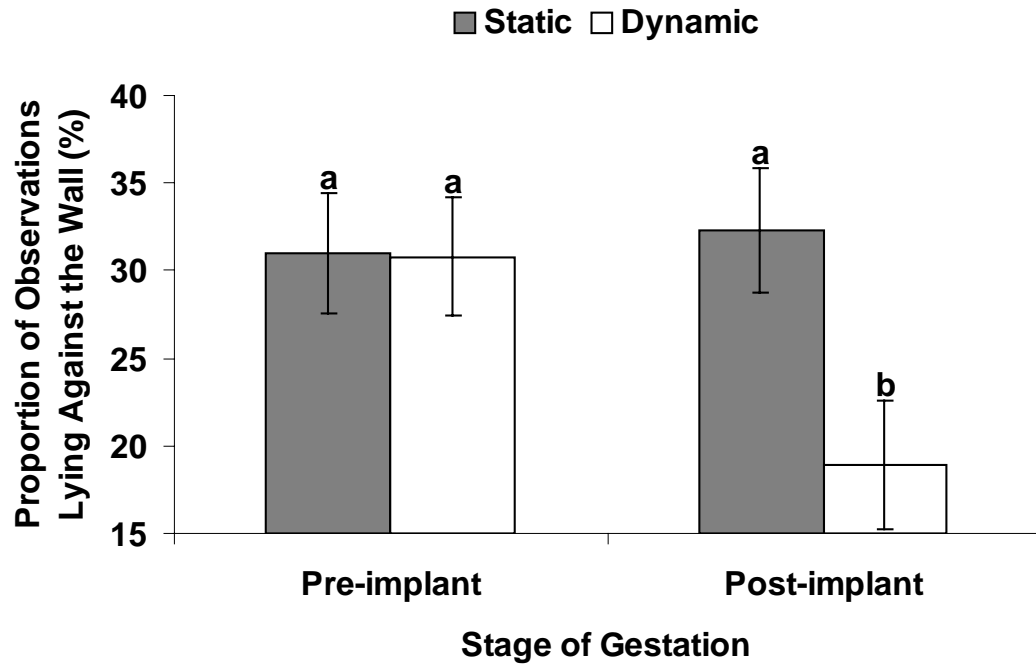
Figure 3.19   The interaction between stage of gestation and housing on the proportion of time sows spent lying against the wall in the solid area of the pen in an Electronic Sow Feeding system (p=0.06). Means without a common superscript differ (p<0.05).
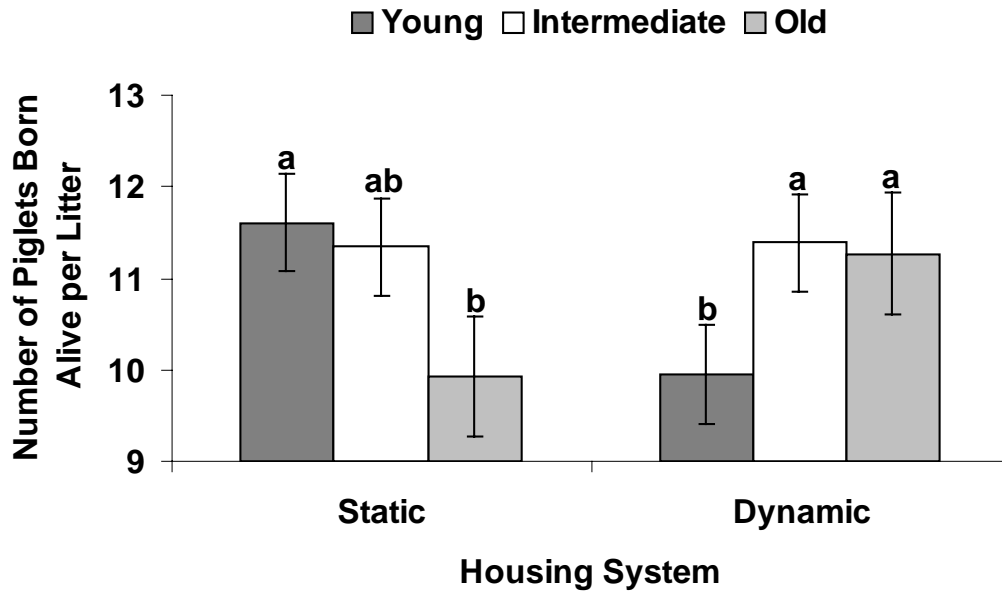
Figure 3.20   The interaction between housing and parity on the number of piglets born alive per litter for sows housed in an Electronic Sow Feeding system (p=0.03). Means without a common superscript differ (p<0.05).

It is important to note that the farrowing rates were not significantly different. However, there were large numerical differences amongst farrowing rates for some of the main effects. Sows housed in a dynamic housing system (89.1%) had a higher farrowing rate than sows housed in static pens (83.1%; χ^2=0.1672; df=1; p>0.05; Table 3.4). Sows that were mixed post-implantation had a farrowing rate of 89.9%, which was higher than the 83.6% farrowing rate of sows mixed pre-implantation (χ^2=0.2909; df=1; p>0.05; Table 3.4). There was not a sizeable difference between the farrowing rates of familiar (87.3%) and unfamiliar (85.2%) sows (χ^2=0.5733; df=1; p>0.05; Table 3.5). Nor was there a significant difference amongst the farrowing rates for the three parity categories. Young sows had a farrowing rate of 83.8%, which was the lowest, old sows had a moderate farrowing rate of 86.1% and the highest farrowing rate was 88.2% for the intermediate sows (χ^2=0.2861; df=2; p>0.05; Table 3.5).

The number of days post-breeding that a sow entered group housing did not significantly affect the sow's farrowing rate (χ^2=0.5580; df=5; p>0.05). However, as seen in Figure 3.21, sows that entered group housing 1 or 2 days after breeding tended to have higher farrowing rates than those sows that entered group housing 4 days or post-breeding.
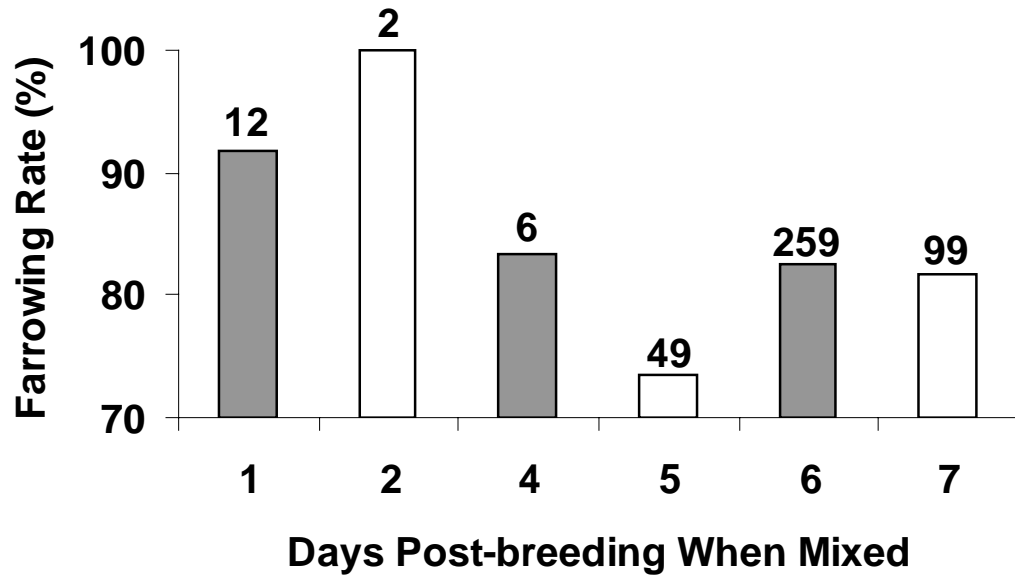
Figure 3.21 The farrowing rate based on the number of days post-breeding at the time of introduction into an Electronic Sow Feeding system. The number above represents the number of sows that data was collected from on each day.

3.4. Discussion

3.4.1. Housing

According to den Hartog et al. (1993), more aggression is expected in a dynamic housing system due to the volatile nature of the system itself. The aggression at mixing in a dynamic housing system is instigated by the resident sows and directed towards the new sows (Mount and Seabrook, 1993). A study by Moore et al. (1993) determined that 87% of the fights that occur at mixing in a dynamic housing system are between resident and new sows.

Durrell et al. (2002) compared aggression levels in static and dynamic systems at mixing, and the aggression levels were higher in the large group dynamic system. The opposite was found in the current study, as there was a tendency for sows in the static pens to spend more time, overall, involved in aggressive encounters immediately following mixing. The study by Durrell et al. (2002) only used an Electronic Sow Feeding system in the dynamic housing system, while the static sows were fed via a stall-feeding system, which would create two different environments within each of the systems and might have caused the difference in aggression levels. As well, Spoodler et al. (1997) did not find a difference in the aggression levels of the resident sows on mixing and non-mixing days, as the majority of the aggression involved the new sows at mixing.

The sows in the static management system may have been involved in more aggression encounters because the dynamic pen was much larger and likely allowed the sows to spread out more, which would prevent aggression.

Overall, there was not a significant difference in the number of aggressive encounters initiated and received at the feeder in either housing system. However, the aggressive encounters extended throughout the feeding period in the dynamic housing system. In the static pens, aggression was most prominent during the first four hours

after the feeder reset. Since there were fewer sows to eat in the static pen, the demand would be high initially following feeder reset, but would quickly diminish once the majority of sows have eaten. In the dynamic housing system, the new sows ate later, thus extending the duration of the high levels of aggression at the feeder.

Housing did not affect any of the three injury scores measured in this experiment. Sows housed in a dynamic housing system typically have more injuries than sows in static pens because the repeated mixings result in fresh injuries (Burfoot et al., 1994; Anil et al., 2005a). Durrell et al. (2002) found that sows in the dynamic housing system always had a higher injury score compared with the score taken from sows in the small static group. A study by O'Connell et al. (2003) examined the injury scores of sows one day and one week after mixing in static and dynamic systems. The two systems were not directly compared, but the dynamic group tended to have a higher injury score than the static group at each scoring (O'Connell et al., 2003). Only, in the current study, at farrowing did the sows housed in the dynamic system had more scratches than those housed in static pens, which was likely because the dynamic sows underwent another mixing a few weeks before they entered the farrowing room. Since there was not a difference in the aggression levels between the static and dynamic housing management systems in the present study, there should not be difference in the injury scores, as the injury scores are a reflection of the aggression levels within the pen.

In the current study, the total injury score of sows housed in the static pens taken 28 days post-mixing was higher than the scores taken on days 3 and 63 post-mixing in the dynamic housing system. The sows in the sows housed in the dynamic system in the current study were not mixed as frequently as they were in previous studies, which may be why there was not a significant difference in the injury scores of sows housed in a static or dynamic management system. Therefore, the welfare of sows housed in the dynamic system was similar to the sows in the static management system, based on injuries, compared with the static housing system.

Housing sows in static pens or a dynamic housing system did not result in differences in the feeder entry order. In a dynamic housing system, Bressers et al. (1993) found that the newly introduced sows tended to eat later in the feeding cycle than the resident sows. Similarly, the resident subgroup ate first, and the majority of the sows in

the new subgroup waited until the sows from the first subgroup were finished eating to access the feeder (van Putten and van de Burgwal, 1990). The feeder entry order of the new sows relative to the resident sows in the dynamic housing system was not examined in the present study.

There was no difference in the salivary cortisol levels between the sows housed in the two different systems. Mendl et al. (1994) had similar findings showing the salivary cortisol concentrations of 10-week-old pigs housed in static and dynamic systems did not differ. In the study by O'Connell et al. (2003), in which direct comparisons were not made between the two housing systems, the salivary cortisol levels of sows housed in the dynamic housing system was higher than the static sows' levels. In the present study, the lack of a difference in the salivary cortisol concentrations between the two housing management systems also illustrates that the repeated regrouping in the dynamic management system does not increase the stress levels of the sows when compared to those housed in a static management system.

The space usage within the static and dynamic systems did not differ. Regardless of housing management, the amount of time that elapsed since mixing affected the space usage within the pen, as during the week of mixing, the sows spent the least amount of time lying in the desirable areas of the pen (on the solid area) and the most time lying on the slats and standing. By the third week post-mixing, sows had already adjusted their space usage to reflect their preference for lying in the solid area of the pen and avoiding the slats and standing.

Moore et al. (1993) examined the space usage of sows in a dynamic housing system. During the first 21 days after regrouping, approximately 70% of the new sows laid in the dunging area of the pen. Moore et al. (1993) also found that 93% of the new group members rested in the dunging area the first night after mixing. The ninth day post-mixing, 80% of the new sows were still resting in the dunging area (Moore et al., 1993).

The complete integration of the new sows into a dynamic group is a gradual process. Fourteen days after mixing, there was still noticeable segregation between the new and resident sows. Complete integration of the new sows into the group did not take place until 21 days post-mixing (Moore et al., 1993), or five weeks post-mixing in a

study by Durrell et al. (2003). Thus, the sows in the dynamic managements system may have formed segregated subgroups, and within the subgroup the space usage should have been reflective of that within the static pen.

In the current study, during the week of mixing, the sows in the static system stood and laid against the wall in the solid area of the pen more than the sows in the dynamic housing system. It was likely easier for static sows to lie against the wall the week of mixing because they did not have to interact with resident sows in the solid area of the pen. The higher amount of time spent standing reflects the unrest that follows mixing in the static pens.

There were no differences between the two housing treatments with respect to the farrowing rate, total number of piglets born and the number of piglets born alive. Past research has found that sows housed in dynamic housing systems typically have a lower farrowing rate than sows housed in static pens. Simmins (1993) found that sows housed in a static housing system had a higher farrowing rate (855 vs. 78% for static and dynamic, respectively). In a later study by Anil et al. (2005a), the farrowing rate of sows housed in static pens was 88% and 82% for sows housed in a dynamic system. The results in this study, although not significant, found that the sows housed in a dynamic housing system actually tended to have a higher farrowing rate than sow housed in static pens.

Mortensen (2000) found that on a per litter basis, sows housed in small static groups had smaller litters sizes than that of sows housed in large group dynamic systems. In the current study, the litter size in each housing system was influenced by the sows' parity. Old sows had fewer piglets born alive when housed in the static pens, while the young sows had fewer piglets born alive when housed in the dynamic housing system. The study by Simmins (1993) also found an interaction between housing systems and parity. Second parity sows housed in static pens had a much higher return to oestrous rate than sows housed in a dynamic system (50% versus 10% in the static and dynamic systems, respectively). The study by Simmins (1993) did not find a difference

in the total number of piglets born or born alive per sow between the two housing systems. In a study by Anil et al. (2005a), the number of piglets born alive, stillborn, mummified and that were weaned did not differ between the static and dynamic housing systems.

Very few studies comparing static and dynamic systems have been conducted. In previous studies, the dynamic group sizes were considerably smaller and the sows were mixed much more frequently (Table 3.11). This study is different from most previous studies, as the current study studied the sows in much larger groups. The static pens housed approximately 35 sows, and the dynamic housing system housed approximately 100.

Drickamer et al. (1999) found that smaller groups of sows were less aggressive than larger groups. However, work in grow/finish pigs suggests that pigs housed in larger group sizes are not necessarily more aggressive. Aggression at the feeder was not affected in groups of 20, 40 or 80 pigs (Spoodler et al., 1999). There were significantly more fights per pig in groups of six or twelve pigs, than in groups of 24 pigs (Andersen et al., 2004). Turner et al. (2001) found that pigs housed in groups of 20 were more aggressive than pigs from groups of 80.

A study by Samarakone and Gonyou (2003) did not find a difference in the aggression levels 48 hours after mixing in grow/finish pigs housed in either groups of 18 or 108. Later results found that when pigs that were previously housed in large groups were introduced into an established large group, there was significantly less aggression than if the pigs were introduced into an established small group (Samarakone and Gonyou, 2003). It is believed that pigs in large groups adopt a non-aggressive tolerant social strategy. Thus, past research in grow/finish pigs suggests that increasing the group size does not automatically increase aggression levels and the same may be true for gestating sows.

As well, the frequency of regrouping may have affected the results in this study, because the number of times the sows were mixed was less frequent than that in previous studies (Table 3.12). In past studies, sows were mixed from once a week (Simmins, 1993) to once every three weeks (van Putten and van de Burgwal, 1990; O'Connell et al., 2003). Jensen et al. (2000) compared four different large group

Table 3.12   A summary of studies pertaining to the group size and frequency of regrouping of sows in static and dynamic group housing systems.

Authors	Number of Pigs in the Pen		Frequency of regrouping in the dynamic pen
	Static	Dynamic	
van Putten and van de Burgwal (1990)	Not studied	40	Every 3 weeks
Simmins (1993)	12	18	Once/week
Hodgkiss and Eddison (1995a,b)	Not studied	55-70	Not stated
Spoodler et al. (1997)	Not studied	~ 25	Every 2nd week
Durrell et al. (2002)*	4	33	Every 2nd week
O'Connell et al. (2003)**	4	40	Every 3rd week

*The static sows were fed via a stall-feeding system and the dynamic sows were fed via a computerized feeding system.
** A direct comparison was not made between the static and dynamic housing systems.

dynamic housing systems, that mixed sows every first, second, third or fifth week. The frequency at which the sows were mixed did not affect the aggression levels. The present study was also unique because the resident sows were all post-implant at regrouping, which as discussed later reduces the aggression levels of the sows.

An article by Barbari et al. (1993) concluded that for a dynamic housing system to be successful it must house a minimum of 80 to 100 sows and three or more feeders should be available. Other studies pertaining to dynamic group sow housing have not examined the system described by Barbari et al. (1993). In this study, the large group dynamic management system resulted in the elimination of deleterious affects associated with a dynamic housing system, as there was not a difference in the aggression levels and the subsequent injuries. As well, there was not a difference in the feeder entry order or the space usage between the two groups. The lack of differences seen in the behavioural parameters examined would indicate that the sows underwent similar levels of stress, which was seen in the present study. Thus, housing sows within a dynamic housing system can be successful, but the success depends on the management techniques utilized.

3.4.2. Stage of Gestation

Little research has been conducted to determine the behavioural differences during gestation of sows that were mixed before or after embryonic implantation, although this is quite important in terms of productivity. Several articles recommend avoiding mixing sows until after embryonic implantation. The optimum time to mix sows is three to four weeks after breeding (Hurtgen et al., 1980; Bokma, 1990; Edwards, 1998).

In this study, whether a sow was mixed pre- or post-implantation did not affect the aggression levels at mixing, injury scores, lying patterns (except the percentage of time lying on the slats) or farrowing productivity. The stage of gestation at mixing did affect the aggression at the feeder, feeder entry order, the percentage of time the sows rested on the slats and the salivary cortisol concentrations.

The sows that were mixed pre-implantation were more docile, and less willing to become involved in aggressive situations. Sows mixed pre-implantation were more aggressive at feeding. The post-implant sows rested on the slats more, which may be indicative of their unwillingness to compete for the preferable lying areas in the pen. Another indication of the post-implantation sows preference to avoid conflict is that they ate significantly later in the feeding cycle than pre-implant.

The aggression levels at the feeder, feeder entry order and the percentage of time spent resting on the slats reflects the change in sow temperament throughout gestation. Although not yet scientifically proven, it is believed that as a sow progresses through the gestation cycle, she tends to become more docile. It has been shown that the concentrations of progesterone and prolactin increase as the sow progresses through gestation (Stabenfeldt and Edqvist, 1993). The increased timidity of the sow could potentially be associated with the increased circulating progesterone and/or prolactin levels.

The sows that were mixed post-implantation had higher cortisol concentrations than the sows mixed pre-implantation. However, this is not necessarily indicative of an increased stress level in these sows. Cortisol levels increase as a sow progresses through gestation (Barnett et al., 1985; Hay et al., 2000). The salivary cortisol concentrations increased as the sows progressed through gestation in this study as well. Hay et al. (2000) found that early in gestation, the mean plasma cortisol concentrations were 12.6 ng/mL, by mid gestation concentrations were 15.5 ng/mL and during the latter part of gestation, the mean plasma corticosteroid concentrations were 19.95 ng/mL. Since the sows mixed post-implantation were at least five weeks further along in pregnancy, they should have had higher cortisol concentrations than the pre-implant sows.

As a point of interest, the highest salivary cortisol concentration taken in this study was 12.61 ng/mL on day 63 after mixing. The salivary concentration from this study was similar to the plasma cortisol concentration recorded during the first trimester of gestation (12.6 ng/mL) in the study by Hay et al. (2000). Even though the sampling and assay techniques differed, this may be an indication that the sows in this study may not have been as stressed as much as sows in previous research.

There was not a significant difference between the farrowing rates of sows mixed pre- or post-implantation. In previous research at the PSC Elstow Research Farm, there has been an 8% difference in the farrowing rates of pre- and post-implant sows (Li, personal communication). In the current study, sows mixed post-implantation had a 6% higher farrowing rate than pre-implant sows, although this difference was not significant because of the low number of sows used in this study.

The data from this study is confounded by the day of gestation (mixed 12 vs. 46 days post breeding for pre- and post-implant sows, respectively). There are two reasons that stage of gestation could have had an effect. The first reason is that the sows were more susceptible to stress at a particular time during gestation while the second reason is that sows underwent more stress because they were more aggressive. Whatever the reason, the data from this study suggests that sows mixed post-implantation are not as willing to engage in confrontational situations to obtain better access to the resources in the pen, and the lack of involvement in potentially stressful situations may have been why these sows had a higher farrowing rate.

3.4.3. Familiarity

In the wild, unfamiliar groups of sows respond to each other's presence by avoiding one another (Mendl, 1995). However, in commercial situations, there is not enough space provided for sows to avoid unfamiliar individuals, which may encourage aggression (Mendl, 1995). According to Puppe (1998), the aggression between unfamiliar sows may be an attempt to drive away unfamiliar sows.

There is a debate in the literature about the cognitive abilities of domestic pigs and this relates to the ability of pigs to discriminate between familiar and unfamiliar conspecifics. According to Stookey and Gonyou (1998) familiarity in pigs is achieved through a period of mutual association. In a recent study by McLeman et al. (2005), young domestic pigs were able to distinguish between a familiar pen mate and an

unfamiliar littermate. Another study found that unfamiliar sows fought significantly more than familiar dyads (Puppe, 1998). Similarly, in the study by Stookey and Gonyou (1998), young pigs that were raised apart fought four times more than pigs reared in the same group.

For familiarity to be relevant in this experiment, it is contingent on the fact that pigs can remember relationships developed over an extended period of separation. In this experiment, the sows were separated for a minimum of four weeks in the farrowing room and one week during breeding. The sows in the post-implantation treatment also had another five to six week period of separation, while they were housed in stalls during the implantation process.

Olsson and Samuelsson (1993) found that sows that had been housed together during the previous gestation cycle had significantly lower levels of aggression. In a study by Arey (1999), the sows were able to recognize previous penmates even after 6 weeks of separation, as illustrated by the fact that at mixing, 93% of the fights that took place were between familiar and unfamiliar sows. An earlier study by Arey and Jamieson (1998) also found that sows could recognize previous penmates after being separated for 4 to 6 weeks.

In general, familiarity did not affect the aggressiveness of the sows at mixing or at the feeder. There was a tendency, at mixing, for familiar sows to spend more time fighting than unfamiliar sows, which is contradictory to the studies previously discussed in which familiarity reduced aggression. The results from the present study are similar to results found by Puppe (1998), as familiarity did not affect aggression levels associated with competition for access to the feed trough.

The introduction of pigs to a new environment may trigger aggression amongst familiar pigs (Stookey and Gonyou, 1998). As well, the extended duration of separation may have been too long for the sows to remember a previous pen mate. Giersing and Andersson (1998) found that a four-week period of separation was too long for weanling pigs to remember previous pen mates. Gilts that were separated for 2 or 4 weeks were unable to remember each other upon regrouping (Spoodler et al., 1996). In a study by Hoy and Bauer (2005), the aggression levels, at regrouping, of sows that were separated for 7 or 28 days were examined. Sows that had been apart for seven days were involved

in fewer aggressive interactions. The higher levels of aggression exhibited in the sows apart for 28 days indicates that they were unable to recall their previous group mates after being apart for four weeks. Thus, it is possible that the sows in this study spent too much time apart, which impaired their ability to effectively recognize familiar sows.

Familiarity did not affect the injury scores of the sows. However, familiar sows tended to have a higher score for abscesses, swellings and cuts. Familiar sows that were mixed post-implantation had a significantly higher total injury score than unfamiliar sows that were mixed post-implantation. The similarity in the injury scores of familiar and unfamiliar sows is to be expected since the two treatments had similar levels of aggression.

Familiar sows laid against the wall more often, while unfamiliar sows lay in the centre of the solid area of the pen more. deKoning (1993) stated that sows in static and dynamic pens form subgroups of 3 to 12 sows at mixing. When a new group of sows is introduced into a dynamic pen, the new sows tend to limit their interactions with the resident sows and interact amongst themselves more (Mount and Seabrook, 1993). Perhaps, in this study, the unfamiliar sows were forming subgroups in the centre area, as there is ample room for small groups of sows to lie together and segregate themselves from the sows lying against the wall.

The amount of time the sows spent standing and lying on the slats was not affected by familiarity. Nor were the feeder entry order, salivary cortisol concentrations and the farrowing productivity. It is important to note that had the sows in the familiar category been acquainted with a greater percentage of sows within the group, the results pertaining to familiarity may have had a more significant effect on the behaviour of the sows. Familiar sows were only familiar with approximately 23.6% and unfamiliar sows were familiar with approximately 8.6% of their current pen mates.

3.4.4. Parity

The effect of parity on the behaviour of group-housed sows has been studied extensively in past research. In addition, research has also examined the effect of dominance on the behaviour of group-housed sows. Studies have determined that parity

was positively correlated with a sow's rank in the dominance hierarchy (Brouns and Edwards, 1994; Arey and Jamieson, 1998), thus making a sow's position in the dominance hierarchy a relevant topic when discussing parity.

A sow's parity significantly affected the levels of aggression. Old sows were involved in more fights and overall spent more time fighting after mixing than sows from the young or intermediate category.

When the number of aggressive interactions initiated and received at the feeder was broken down into the three periods, there was a difference in the number of aggressive encounters initiated and received at the feeder. Young sows initiated fewer aggressive encounters immediately after the feeder reset, which is when aggression at the feeder is most prominent, thus the young sows appeared to be less aggressive. Also the low levels of aggressive encounters initiated by the young sows is related to the feeder entry order, as the young sows ate later in the feeding cycle, when aggression levels were much lower. Therefore, after the feeder reset, the young sows did not approach the feeder entrance, which would explain the low number of aggressive encounters initiated by these sows.

Mid-way through the feeding cycle (19:00 to 23:00h), sows in the intermediate category, second and third parity sows, received more aggressive encounters than the old sows. This likely relates to the feeder entry order, as even though the difference was not significant, the old sows tended to enter the feeder before the intermediate sows. Thus, the intermediate sows would have had to wait until the old sows had finished eating so they could access the feeder, and older sows tend to return to the feeder after eating (Hunter et al. 1988; Tanida et al. 1993; Weber et al. 1993).

A study by Mount and Seabrook (1993) did not find a relationship between parity and aggression at mixing. A study by Arey (1999) found that the number of fights a sow was involved in was positively correlated with rank. Dominant sows are typically more aggressive than lower ranking sows (Mendl et al., 1992; Weber et al., 1993; Otten et al., 1997). The dominant sows also tend to win more aggressive encounters than

subordinate sows (Martin and Edwards, 1994). This suggests that older sows were more aggressive than younger sows, which is consistent with the finding of this study. The older sows in the present study were likely more aggressive at mixing, as they were trying to reaffirm their higher rank within the dominance hierarchy.

A study by Hunter (1988) found that the eating order and the social hierarchy of sows were positively correlated with parity. The high-ranking sows typically eat first (Rantzer et al., 1988; Weber et al., 1993), which means older sows typically eat before young sows. Ranzter et al., (1988) noted that the smaller, weaker sows tended to eat later in the feeding cycle. A study of the eating order in a dynamic housing system found that sows with high social status ate first, and the lower ranking sows were displaced from the feeder more frequently (O'Connell et al., 2003). In a stall-feeding system, the dominant sows were displaced from the feeder and bitten less often than lower ranking sows (Andersen et al., 1999). Similar to previous findings, the young sows in this study ate significantly later in the feeding cycle compared with intermediate and old sows, which is likely related to their lower position in the dominance hierarchy.

The severity of the aggression and outcome of the level of aggression that sows are involved in, is reflected in the damage to the integument. In this study, the young sows tended to have a higher scratch score than old or intermediate sows, which is similar to previous findings in the literature. Spoodler et al. (1997) found that second parity sows had fewer lesions than first parity sows. Hodgkiss and Eddison (1995a) found that the total injury score decreased as the parity of sows increased, and this was because the older sows were less susceptible to attacks. A subsequent study by Hodgkiss et al. (1998) found that first, second and third parity sows received more severe injuries than older parity sows. Anil et al. (2004) found that as a sow's parity increased, her injury score decreased. In terms of previous work pertaining to the effect that sow social status has on injuries, one week after mixing, sows with low social status had more injuries (O'Connell et al., 2003), similar to the findings of the current study.

Contrary to the findings of this study, Broom et al. (1995) found that as sows in an Electronic Sow Feeding system became increasingly familiar with the regrouping process, their aggression levels decreased. A later study by van Putten and Buré (1997)

also found that gilts that were mixed more frequently were less aggressive. Based upon the high scratch score of the young sows, this may be true. The older sows were likely directing their aggression towards the inexperienced first parity sows.

Past studies have found that cortisol concentrations vary between sows of different parities. Several studies have found that the dominant and subordinate ranking sows had the lowest cortisol concentrations. The highest cortisol levels were recorded in intermediate ranked sows (Mendl et al., 1993; Nicolson et al. 1993; Zanella et al., 1998). Tsuma et al. (1996b) found that the salivary cortisol concentration rose in all sows on the day of mixing. However, the increase was the most significant in the intermediate ranking sows.

Contrary to those findings, this study found that sows in the intermediate parity category had the lowest salivary cortisol concentration, and young and old sows had the highest concentrations. Otten et al. (1997) found that dominant sows had the highest cortisol levels. When studying tethered sows, Barnett et al., (1989) found that the subordinate sows had the highest cortisol levels. In the study by Tsuma et al. (1996b), in the days following mixing, cortisol concentrations remained elevated in the dominant sows and decreased in the subordinate sows. More importantly, the cortisol concentrations of intermediate ranking sows also decreased, but they returned to pre-mixing values.

Anil (2004) observed a positive correlation between the number of aggressive encounters performed and received and the salivary cortisol concentrations. In this study, older sows had higher cortisol concentrations and these sows were involved in more aggressive encounters. The young sows also had higher cortisol concentrations, and due to the high number of scratches on these sows, it is likely they were the ones receiving the aggression from the old sows, which would explain the higher cortisol concentrations seen in these sows.

The space usage within the pen was also affected by parity, as old sows spent a higher percentage of their time lying against the wall in the solid area of the pen and the least amount of time lying on the slats. The amount of time young and intermediate sows spent lying against the wall did not differ, but young sows did lie on the slats more than intermediate sows. A study by Hodgkiss and Eddison (1995b) found that old sows

occupied the more favorable resting areas, such as the space adjacent to walls and in the corners. O'Connell et al. (2003) observed the lower status sows rested in the kennel area significantly less than higher ranking sows.

The amount of time that has elapsed since mixing also affects the amount of time the sows use the slats as a resting area. During the week of mixing, young sows spent the most time lying on the slats, which is similar to the findings of Hodgkiss and Eddison (1995b), as after mixing, the gilts frequently used the dunging area for resting, and it took one to two weeks for the gilts to be integrated into the group. During the first week after mixing, the newly introduced gilts spent a significant proportion of their time away from the resident sows within the group (Grigoriadis et al., 2000).

There also was a tendency for the percentage of time the sows spent lying in the center of the solid area of the pen to be affected by parity. During the week after mixing, the intermediate sows were recorded lying in the center more than the young sows. However, by the third week post-mixing, the intermediate sows were now using this area more than the old sows.

In terms of farrowing rate, this study had the same results as those found by Karlen (2005), in that there was not a difference in the farrowing rates between the different parity categories. Nicholson et al. (1993) found a sow's rank affected the farrowing rate. Intermediate ranking sows had a lower farrowing rate (60%) than dominant and subordinate sows (90% and 87.5%, respectively).

Parity also did not affect the total number of piglets born and the number of piglets born alive. Petherick and Blackshaw (1989) did not find a difference in the number of piglets born alive in sows in their 2nd to 6th parity. However, sows in the higher parity categories, had fewer piglets born alive and more stillborn piglets.

Therefore, the intermediate, second and third parity sows within the group underwent the least amount of stress because of their intermediate position within the dominance hierarchy. The old sows underwent more stress trying to maintain their high-ranking position within the hierarchy. The lower ranking, young sows underwent more stress because they had to wait to access the preferred resources within the pen.

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3.4.5. Time Since Mixing

The amount of time that elapsed since mixing affected a number of the
parameters examined. More aggressive encounters were initiated and received at the
feeder 28 and 63 days post-mixing. Anil (2004), found that the number of aggressive
encounters was positively correlated with the percentage of time queuing, and sows
tended to queue more frequently later on in gestation. As well, the energy requirements
for fetal development increase later in gestation (Clark, 1990), which may have led to
the increased demand for access to the feeder.

The severity of each of the injury scores taken was also dependent on the amount
of time since the sows were mixed. The lowest scores tended to be taken before mixing,
or while the sows were in the farrowing room and the highest score were taken on weeks
3 and 8 post-mixing. In this study, the scratch score was also significantly higher the
week of mixing. Grigoriadis et al (2000) found that the lowest lesion scores were taken
before mixing and the maximum lesion score was recorded immediately after mixing.
Anil et al. (2004) recorded the highest total injury score the week after mixing.

Karlen (2005) noted that the number of scratches on a sow decreased as she
progressed through gestation. In this study, the peak scratch score occurred the third
week post-mixing, after said time the score began to decline. Spoodler et al. (1997)
found that skin lesions increased the week of mixing and declined thereafter. Hodgkiss
and Eddison (1995a) found that the total injury score decreased through gestation.

The reason for the extended elevation in the scratch score in this study, was
likely that fresh and healed scratches were both counted in the score. If only fresh
scratches would have been counted, it is quite likely that the scratch score would have
reached its peak the week of mixing (Spoodler et al., 1997). However, a past study found
it quite difficult to distinguish between a fresh and healed scratch (D'Eath, 2002), which
is why both fresh and healed scratches were measured in this study.

The time of day also affected the aggression levels seen at the feeder, as fewer
aggressive encounters were initiated and received at the feeder during the later part of
the feeding cycle (23:00 to 06:00 h) than during the beginning (15:00 to 23:00 h). The

lower demand for the feeder after 23:00 h is likely because the majority of the sows had finished eating, and they were likely sleeping, as sows have a diurnal activity pattern (Jensen et al. 2000).

There was also an interaction between the time of day and the amount of time since the sows were mixed. On day 28 post-mixing, the highest number of aggressive encounters occurred during the first two periods, while on day 63 post-mixing the peak number of aggressive encounters occurred during the first part of the feeding cycle and declined thereafter.

3.5. Conclusion

Under the conditions of this study, the behaviour, physiology, productivity and welfare of sows in a dynamic system was equivalent to that of sows housed in a static system. Thus, a large group dynamic management system is an acceptable management strategy. However, the similarities in the static and dynamic management systems are likely due to the environment within the dynamic system. The dynamic system used larger groups, mixed the sows less frequently, and did not repeatedly mix the sows during embryonic implantation. That is important as this study also found that sows mixed after embryonic implantation are more docile than sows mixed pre-implantation. When the sows were mixed post-implantation, they were not as aggressive and the demand for resources was less intense.

This study did not find a benefit from housing group mates from previous gestation cycle together. However, the proportion of animals that were familiar with each other was quite low. If the familiar sows had been familiar with a greater percentage of sows within the pen, there may have been an advantage to housing previous group mates together.

Parity significantly affected the behaviour of sows housed in an Electronic Sow Feeding system. The first parity sows were generally subordinate, which resulted in them eating later in the feeding cycle, and using the slats as a resting area more than sows in their second parity or higher. Even though the first parity sows were not

involved in high levels of aggression, they had a higher scratch score than the other sows within the group. The stress relating to the inability to access the resources may have been the cause of the higher cortisol concentration measured in these sows.

The sows in their fourth parity or higher had the best access to resources within the pen, but it came at a cost, as they were the most aggressive sows within the group. The high levels of aggression appeared to be quite stressful, as the older sows within the pen also had significantly higher cortisol levels. Thus, it appears that the second and third parity sows are undergoing the least amount of stress when they are group housed because of their intermediate position in the dominance hierarchy.

4. IMPLICATIONS

A dynamic management system can be an effective system for group-housed sows using an Electronic Sow Feeding system. However, for a dynamic management system to be successful, there are several management strategies that are key. A dynamic management system should be used for large groups (>80 sows), have multiple Electronic Sow Feeding stations and the sows should only undergo one mixing during implantation, at the most. Regardless of the type of housing management, mixing before and during embryonic implantation should be avoided. Post-implant sows are more docile, which reduces problematic aggression and competition over resources within the pen. Parity also needs to be considered, as parity affected the aggressiveness and stress levels of the sows.

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