EFFECTS OF SOW GROUPING PRACTICES ON PRODUCTION AND MIXING AGGRESSION

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Submitted by
Jessica Vehof

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OR

Dean

College of Graduate and Postdoctoral Studies

University of Saskatchewan

116 Thorvaldson Building, 110 Science Place

Saskatoon, Saskatchewan S7N 5C9 Canada

Overall Abstract

As the Canadian swine industry transitions gestation housing from stalls to groups, it is important to understand the impact of different grouping practices on sow productivity and welfare. When sows are housed in groups, a social hierarchy is established through aggressive behaviour which can negatively impact production. Many producers are implementing dynamic groups and early mixing using precision feeding; however, there is potential for greater aggression and the consequences of this practice are not fully known.

This study compared the effects of three grouping treatments in gestation on sow productivity and aggression. Treatments included: Control (Con): sows housed in stalls for 35 days after insemination, then moved to static groups; Static (Sta): sows mixed into static groups 1-8 days after insemination; and Dynamic (Dyn): sows mixed into dynamic groups 1-8 days after insemination with monthly mixing (8-10 sows removed and replaced). Mixed parity sows and gilts were housed in groups of 25 per pen in three replicates per treatment. Body weight, body condition score and backfat thickness were recorded once at breeding and again when sows were moved to farrowing. Farrowing rate, litter characteristics and piglet birthweights were recorded. On the day of mixing, sow behaviour was video recorded for measurement of reciprocal and one-sided aggression. Skin lesions and lameness were scored before and after mixing, at ~day 63 of gestation, ~day 91 of gestation, and on the day of moving to farrowing. Hair samples were collected at 7- and 12-weeks post-insemination for cortisol analysis. Statistical analysis was performed in SAS 9.4 using mixed effects models and Chi-square analysis.

Grouping practice did not have a significant effect on change in body weight, backfat thickness or body condition during gestation. Farrowing rates for Con, Dyn and Sta treatments were 81%, 88% and 62%, respectively (Chi sq $p<0.001$). There were no significant treatment differences for litter characteristics. At mixing, Sta sows had a higher frequency of reciprocal fighting in the first half hour (Chi sq $p<0.001$), than did Con or Dyn sows. However, during the 24 hrs following mixing, sows in the Con treatment received more lesions in total than did Sta or Dyn sows (means ±SEM: Con: 11.71 ±0.46; Dyn: 8.69 ±0.40; Sta: 9.09 ±0.41, $p<0.01$)). Lesion scores decreased significantly over time in all groups. Throughout gestation, Dyn sows had higher lesions overall and a higher incidence of lameness than either Con or Sta sows ($p<0.001$ and $p=0.046$, respectively). Although treatment had no effect on hair cortisol concentrations, parity group had a significant effect on concentrations at both timepoints with young sows having the highest concentration and mid parity sows the lowest ($p=0.04$, $p<0.01$, respectively).

In conclusion, Con and Sta sows appeared to be more aggressive at mixing while aggression in Dynamic groups appeared to be moderated due to the smaller number of unfamiliar sows introduced at each mixing event. Dyn sows had more lesions and increased lameness overall during gestation suggesting increased chronic aggression for dynamic sows, although the results were not severe enough to impact farrowing rate or litter quality. In conclusion, dynamic mixing may serve as a viable housing alternative for pork producers provided that the management strategies are implemented to mitigate the effects of ongoing aggression.

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ACTH: Adrenocorticotropic Hormone

ASF: African Swine Fever

AUP: Animal Use Protocol

BCS: Body Condition Score

CCAC: Canadian Council on Animal Care

CRH: Corticotrophin Releasing Hormone

DIV: Dominance Index Value

ESF: Electronic Sow Feeder

HPA: Hypothalamus Pituitary Adrenal

HPG: Hypothalamic Pituitary Gonadal

LH: Luteinizing Hormone

NFACC: National Farm Animal Care Council

NIP: Not-in-pig

NRC: National Research Council

PSC: Prairie Swine Centre

SAM: Sympathetic Adrenal Medullary

1.0 LITERATURE REVIEW

1.1 Introduction

Farming systems have become more intensified to meet the growing demand for food as the world population continues to increase. Although intensification helps meet these new food production demands, implications for animal well-being arise, as a consequence. A main welfare concern in the swine industry is the confined housing of pregnant sows in gestation stalls as it diminishes the animals' freedom to express normal behaviour; one of the five globally recognized requirements for animal welfare (Farm Animal Welfare Council, 2009; World Organisation for Animal Health (OIE), 1924). Before examining the drawbacks of confinement housing and discussing alternative options along with knowledge gaps in this area, it is important to understand how pigs behave in a natural environment.

1.1.1 Swine Behaviour in a Natural Setting

It is known that domestic animals have conserved most of the behaviour repertoire of their wild progenitors (Jensen et al., 2008). As such, the needs of domesticated animals resemble those of their ancestors (Jensen et al., 2008). To better understand the behaviour of domestic animals, ethologists look at how they behave in a natural setting. The establishment of a small pig population in a semi-natural enclosure consisting of woodland and bog helped researchers study the behaviour of domesticated pigs (Stolba and Wood-Gush, 1989). The group typically included both an older and younger boar, four sows, and an immature gilt. Through a series of experiments observing this group, it was discovered that pigs demonstrate strong exploratory behaviour, especially when introduced into a new environment (Wood-Gush et al., 1990). In relation to social interactions, pigs in small groups have a more stable dominance hierarchy that is maintained by the subordinate animals demonstrating avoidance behaviour rather than the dominant animals showing aggressive behaviour (Keeling & Gonyou, 2001; Jensen & Wood-Gush, 1984).

Similar observations were made in other studies that observed pigs in semi-natural environments. Martínez-Macipe et al. (2020), who studied behaviour of pigs housed in free-range systems, discovered that pigs dedicate about 50% of their daily time budget to exploratory behaviour, however; if the pigs were provided with food, exploratory behaviour decreased significantly while resting behaviour increased. In terms of group structure, Rodríguez-Estévez et al. (2010), observed that during the day, pigs in a large group divide into smaller groups to forage and then will re-group in a common resting area at night. Based on this observation, the authors discussed that large groups seen on intensive operations could be considered natural provided they were given enough space (Rodríguez-Estévez et al., 2010). The observations of pigs in semi-natural environments indicate that pigs are naturally herd animals residing in small groups with a well-maintained social status and typically spending a large amount of time exploring their environment in search of food.

1.1.2 History of Housing Gestating Swine

In the 1700's and early 1800's, raising animals for food production was a normal part of life for rural families. During this time period, the agrarian method of raising animals was common which consisted of raising small groups of animals who had outdoor access and were fed and closely cared for by members of the family (Fraser, 2008).

After the Second World War, however; in response to an increasing demand for food, livestock production systems became intensified toward more confined production systems to provide better food security (Fraser, 2005). One of the major changes with intensification was the confinement of animals for easier handling and space saving, thus livestock producers were able to specialize management to increase production per animal and per labour unit (Udo et al., 2011). In the swine industry, high levels of confinement were most notable in the housing of pregnant sows. By the 1990's, most pregnant sows were being housed in individual gestation stalls (McGlone & Salak-Johnson, 2008), which are metal enclosures that allow the sow to stand up and lie down and take a couple steps forward and back but does not allow enough room for the sow to turn in a full circle (Shield et al., 2017). In commercial operations during this time, sows were kept in stalls for breeding and for the majority of pregnancy until being moved to a farrowing crate, another restrictive form of housing. Although gestation stalls are convenient for ease of management, allow for restricted feeding, reduce the spread of disease and limit aggression, they severely restrict animal movement and limit the ability of sows to socially interact with each other, which the public attributes great importance towards (Ryan et al., 2015). This restriction of movement does not allow the sows to perform natural behaviours and leads to the development of stereotypies such as bar biting, vacuum chewing and drinker playing, thus affecting the sows' quality of life (Sekiguchi & Kotetsu, 2004). Further, Cabib (1993) suggests that stereotypic behaviours arise as a coping mechanism in response to chronic stress induced by stall housing. The confinement of gestating sows to individual stalls has since developed into a controversial issue for the swine industry.

In response to the societal concerns regarding the confinement housing of livestock animals, the European Union banned the use of gestation crates on new farms in 2003 and set out to completely transition to alternative housing by 2013. Some states in the United States later made similar announcements with regards to phasing out gestation stalls (McGlone & Salak-Johnson, 2008). In Canada, efforts to improve swine welfare during gestation, came with the release of the Code of Practice for the Care and Handling of Pigs in 2014. Regarding housing for gestating sows, the Code document described the requirement that "for all holdings newly built or rebuilt or brought into use for the first time after July 1, 2014, mated gilts and sows must be housed in groups" (NFACC, 2014, pg. 11). Furthermore, it required that the complete transition to alternative housing be complete by July 1, 2024. The Code included an alternative for producers to keep the stalls provided that the sows were given "greater freedom of movement" (NFACC, 2014, pg. 11). This suggestion has since been proposed to be removed as periodic exercise is impractical to add in a meaningful manner (Tokareva et al., 2021). Unfortunately, due to the underestimated complications involved with this housing transition, it was identified in the 'Pig Code Five-Year Review' that not all Canadian producers will be able to convert to groups by the 2024 deadline. Therefore, the NFACC Code Amendment Committee published a review in 2020 recommending that the code be amended by extending the deadline to the year 2029 (NFACC, 2020, pg. 19).

The complexities involved with housing sows in groups are numerous making the transition from individual housing a challenge. Feeding sows in groups is one of the most important challenges as gestating sows are feed restricted. As such, the sows view feed as a highly competitive resource. Smaller static groups are more stable but options for implementing new technology that limit competition at feeding, such as electronic sow feeders (ESF), are limited due to cost-effectiveness. Thus, many producers are implementing dynamic groups and early mixing using precision feeding offered by ESF's; however, the consequences of this practice on sow behaviour and production are not fully known.

In response to the mandated housing transition from individual to groups of gestating sows, this literature review was conducted with specific attention on grouping management of gestating sows in open housing systems. The focus of this review is on the evaluation of different management practices and their effects on sow behaviour and welfare as well as production performance. The two main questions that are poorly understood when grouping sows is the effects of timing of mixing (pre- or post- implantation) and whether to mix the sows into static or dynamic groups. The answers to these management questions will depend partly on the design of the barn but also on which systems offer the best welfare and performance for the sows which is currently poorly studied.

1.2 Animal Welfare and Group Housing

1.2.1 Animal Welfare Science

In the 1950's and 60's, society began paying attention to issues beyond personal survival and wealth and greater attention was given toward the ethical concerns regarding the use and treatment of animals (Fraser, 2008). The field of animal welfare science has emerged with the rise in ethical concerns regarding the management of animals by humans. Animal welfare science is known as a mandated field of science because society mandates that these concerns be properly investigated in order to draw conclusions regarding how animals should be treated and managed by humans (Fraser, 2008). Goals of animal welfare research thus aim to settle debates concerning the ethics of raising animals for food production and to provide evidence to guide recommendations for raising animals that provide good welfare and address their behavioural needs (Fraser, 2008). The first response to address these animal welfare concerns came in 1965 by the British Government with the establishment of the Brambell committee, whose task was to investigate 'the welfare of animals kept under intensive livestock husbandry systems' (Brambell, 1965).

Animal welfare researchers then began efforts to define animal welfare and how it could be evaluated. Fraser (2008) identified three re-occurring themes that arose when the constitution of a good life for animals was debated: animal health and function, positive affective states, and natural living. Similar themes are noted in the animal welfare assessment program Welfare Quality® which defines four principles of welfare: good health, good housing, good feeding and appropriate behaviour. Furthermore, the Five Freedoms (namely: freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury and disease; freedom to express normal behaviour; freedom from fear and distress) defined by the Farm Animal Welfare Committee, provides five criteria for good welfare by incorporating the three re-occurring themes of health, affective states and natural living (FAWC, 1993).

1.2.2 Dimensions of Animal Welfare

Animal welfare is not a straightforward concept. Each individual person has their own views on what constitutes a good life for animals, hence, in this literature review, animal welfare will be discussed using the three dimensions defined by Fraser (2008), namely: animal health, affective states and natural living. These dimensions share important concepts with the Five Freedoms, thus overlapping concepts will highlight important indicators of animal welfare.

Animal health and biological function is an important underlying dimension of animal welfare, especially for livestock farmers who consider it a priority (Molnár & Fraser, 2021). A healthy animal is free from pain, injury or disease (FAWC, 1993) and can thus perform to their full potential. Biosecurity, defined as applying measures that aim to reduce the likelihood of new pathogens entering or exiting the facility and reducing the spread of pathogens within and out of the farm (Alarcon et al., 2021), is thus imperative to protecting the pigs from diseases such as African Swine Fever (ASF), which severely affect production (Fasina et al., 2012). The concept of biosecurity is of greater importance in intensive systems where livestock are housed in a tighter density, compared to being housed with greater space provision such as outdoors, increasing animal contact and the speed at which disease can spread within the herd, impacting production (Alarcon et al., 2021). Although the argument that good health can be equated with good welfare as the animal is producing well has been proposed, physical health and function are not sufficient by themselves to determine an animals' welfare status.

Affective state is a second dimension of welfare which emphasizes the importance of animals' mental states and where good animal welfare means that the animal is free from the negative affective states of fear and distress (FAWC, 1993). Moreover, an increase in attention to positive affective states has been made. For example, Douglas et al. (2012), found that pigs housed in an enriched environment had a more optimistic judgment bias which they linked to a more positive affective state. In the context of sow gestation, being confined to a narrow stall increases stereotypic behaviours and time spent sitting, both used as evidence of negative affective states which could be avoided by allowing the animal more room to perform natural behaviours (Hemsworth et al., 2015).

A third dimension of animal welfare focuses on natural living. The definition proposed by Yeates (2018) defines it as 'unaffected by man'. In this case, swine housing would simulate the environment of the ancestor of the domestic pig, the Wild boar (*Sus scrofa*). Elements of a natural housing design for sows would include a small group size with ample space, access to the outdoors and minimal confinement. Other aspects of natural living focus on the ability of the animal to perform their species-specific behaviour. According to a 2014 survey of Canadian citizens, access to natural environments and the ability to express natural behaviours are considered necessary for animals to lead a good life (Spooner et al., 2014). Within the Five Freedoms, the freedom that is associated with natural living states that animals should have the freedom to express normal behaviour (FAWC, 1993).

Although confinement housing can reduce injury and protect the physical health of animals, it negatively impacts affective states and limits the animals' ability to perform its natural behaviour. This literature review will focus on assessing animal welfare in terms of health and function and affective states as analysed through swine behaviour, performance and stress physiology. In this regard, to satisfy all dimensions of animal welfare, options for alternative housing systems need to be explored.

1.2.3 Comparison of Stall Housing to Group Housing

Individual stall housing severely restricts movement of sows and limits their ability to socially interact with herd mates which can impact their psychological wellbeing. If freedom of movement is accepted as being necessary for good welfare, then stall housing reduces animal welfare. However, the alternative to individual housing is group housing. Group housing increases the ability to express the requirement for freedom of movement, and thus should ideally result in better welfare. However, when domestic pigs are mixed into a group, they establish a social ranking through aggressive encounters. These encounters can lead to injuries such as skin lesions and lameness which can diminish sow welfare. Research comparing individual stalls to group housing has shown some conflicting results in terms of sow welfare. Compared to sows housed in groups, sows housed in individual stalls showed increased stereotypical behaviour, higher cortisol levels and differing postural behaviours in late gestation (Zhou et al., 2014; Karlen et al., 2007; Jang et al., 2015; Liu et al., 2021). In addition, an EU report indicates that sows in stalls had reduced bone strength and higher resting heart rates (Von Borrell et al., 1997). However, social aggression in groups can have a negative impact on production. For example, Choe et al. (2018) found an increase in litter size from sows housed in stalls compared to group housing which the researchers explained might be due to the group housing treatment having a competitive feeding system which resulted in additional aggression for access to feed.

The obvious alternative to individual housing is group housing. Although group housing satisfies the criteria for good welfare for animals, sows in a group environment perform aggressive behaviour when establishing their social hierarchy (Krauss & Hoy, 2011) and when competing for feed (Li, 2020). Severe aggressive behaviour can lead to reproductive failure and injury to the sow (Choe et al., 2018; Bos et al., 2016; Knox et al., 2014; Karlen et al., 2007). Additionally, subordinate sows may receive more aggression and their access to feed and other pen resources can be limited. As such, it is important to properly manage sows housed in groups to mitigate the negative effects of aggression at mixing as well as ongoing competition for access to feed and other resources. The challenge is that group housing varies in many aspects, including feeding system, stocking density, and management strategies. As such, the existing literature has differing conclusions regarding the welfare and performance of sows in group housing which will be further discussed in section 1.5.

1.3 Stress Physiology

1.3.1 Causes and Consequences

Including stress physiology in this review is useful to understand the negative consequences, such as reproductive failure, that can arise because of stress. In the review of stress in swine conducted by Martinez-Miro et al. (2016), the causes of stress were divided into five main types: social, environmental, metabolic, immunological and due to human handling. In the scope of this literature review, social stress is most important as it occurs during both isolated individual housing and during re-grouping of unfamiliar sows at weaning and/or during gestation.

When pigs are mixed, fighting to establish a hierarchy is a source of stress that triggers several biological responses including behavioural, neuroendocrine and immunological (Martinez-Miro et al., 2016). Of these responses, the behavioural and neuroendocrine responses are most applicable for this review and will be discussed here. Mixing stress is not generally seen in wild groups of pigs as the groups consist of related females and their juvenile offspring. When unfamiliar groups encounter one another in the wild, they typically avoid contact or drive the other group from their territory. When experiencing stress due to mixing, sows have different behavioural options to respond to aggressive encounters including to avoid the aggression or pursue it. Depending on the housing design, avoiding or hiding may be difficult especially at lower space allowances. Not only does social stress directly affect the sow, research has shown that the maternal behaviour of sows that experienced stress during gestation is poorly affected as indicated by greater pre-farrowing postural changes and greater post-farrowing responsiveness to piglets when they approached the head of the sow (Jarvis et al., 2006).

Physiologically, when facing a short-term stress (i.e. mixing aggression), the first neuroendocrine pathway that is activated is the sympathetic-adrenal-medullary response, otherwise known as the SAM axis. This response is activated when a stress stimulus triggers sympathetic neurons to secrete norepinephrine. Once the stimulus reaches the adrenal medulla, the chromaffin cells also release epinephrine into the blood. Consequences of this response include increased heart rate and blood pressure, and reduced gastro-intestinal processes. These physiological changes mobilize energy resources, preparing the animal to face the stressful stimulus or to escape from it (Martinez-Miro et al., 2016).

In more extreme cases of stress, as well as excitement or arousal, the hypothalamus-pituitary-adrenal (HPA) axis is also activated. In this secondary stress response, upon stimulation of a stressor, the hypothalamus releases corticotrophin releasing hormone (CRH) which triggers the pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH travels in the blood to the adrenal cortex which triggers the release of glucocorticoids which then increase glucose concentrations in the short term. Longer term responses following chronic HPA activation include reduced secretion of sexual and growth hormones and reduced immune activity.

Although the exact physiological mechanisms are still unknown, there is clear evidence that pregnancy losses can be related to stress (Nepomnachy et al., 2006). The hypothalamic-pituitary-gonadal (HPG) axis is a third stress response worth mentioning as its activation directly impacts reproduction which is an important consideration for gestating sows. Glucocorticoids, released by the HPA axis, inhibit the release of luteinizing hormone (LH) from the pituitary gland and estradiol and progesterone secretion from the ovaries (Witorsch, 2015). The effects of this are significant as the circulation of progesterone is essential to maintaining pregnancy. By analyzing the effects of manipulated LH secretion, it was suggested that chronic stress lasting for more than two days during the embryonic stage, compromises luteal function and can result in pregnancy loss (Peltoniemi et al., 2016). A research review conducted by Pedersen-MacNab et al. (2019), identified knowledge gaps in terms of effective methods to reduce aggression at mixing as well as the pre-natal effects of group housing on offspring.

1.3.2 Measuring Stress

Two main methods to quantify stress in animals include the use of direct behavioural observations and the use of biomarkers (Martinez-Miro et al., 2016). When evaluating stress in pigs, one of the most widely used biomarkers is the glucocorticoid cortisol. Although cortisol is the main glucocorticoid in pigs (Bottoms et al., 1972), there are some limitations to using it as a measure of stress. One of the limitations of using cortisol is the fact that systematic levels change naturally throughout the day as cortisol follows a circadian rhythm (Bottoms et al., 1972; Ruis et al., 1997). This limitation requires specific planning of when the samples are taken. A second limitation is that cortisol release can follow an inverted 'U' response pattern, with low levels present both in the absence of stress and in extreme or chronic stress (Miller et al., 2007). Other limitations include high individual variation and the sampling process itself which can cause stress thus influencing the results. The collection of blood is an invasive method used to collect samples of cortisol as it requires restraining the animal and the puncturing of a needle, both of which are painful and stressful procedures. Saliva, feces and hair, are alternative sample matrices for measuring cortisol that are less invasive and thus less stressful.

Recent research has shown that cortisol sampled from hair can be used as an indicator of pig welfare (Carroll et al., 2018). As opposed to getting an instantaneous measurement of stress, hair cortisol is deposited gradually over time as the hair follicle grows and thus provides an option to analyze stress occurring over a period of time (Russell et al., 2012). Hair has a predictable growth rate which is advantageous as it will determine collection times. Additional advantages of using cortisol extracted from hair include, cortisol levels can provide a baseline assessment by collecting during a time when stress had not occurred, non-invasive collection by shaving with a set of razors, and easy storage (Russell et al., 2012). It is important to note that the evaluation of hair cortisol is novel and the relationship between stress cortisol levels in hair is not yet well understood.

1.4 Behavioural Responses

1.4.1 Social Status and Agonistic Behaviours

It has been well established that pigs living in groups establish a hierarchy whereby individuals hold different social ranks. The social rank of sows is used to determine who gets first access to limited resources, such as feed. When first mixed into groups, the formation of a social hierarchy is a complex process which is established by the expression of agonistic behaviour (Arey, 1999). An ethogram for social interaction patterns of dry sows housed in groups is described by Jensen (1980) and includes direct fighting behaviour such as head-to-head and head-to-body knocks and bites.

One of the first studies to research the nature of hierarchal groups determined that aggressive fighting stops within the first 24 hours of mixing and the social order of a group of 8-week-old pigs was fixed within 48 hours (Meese & Ewbank, 1973). The effects of agonistic behaviours on reproductive performance of sows have also been researched. For example, in the social structure of a group of sows, higher ranking sows have higher farrowing rates and larger litter sizes than low ranking sows (Hoy et al., 2009).

Dominance ranks in sows have been assigned by observing the outcomes of agonistic behaviours (Meikle et al., 1996; Hoy et al., 2009; Norring et al., 2019). Aggression at mixing reduces reproductive performance and may even have negative effects on the performance in subsequent parities (Lagoda et al., 2021). Therefore, since aggression can not be eliminated at mixing, research is needed to determine the mitigation techniques that can be used to reduce the effects of aggression on sows. These techniques may include providing enough space allowance, using non-competitive feed systems and grouping compatible sows together (Remience et al., 2008; Horback et al., 2021).

Many studies have used skin lesions, an outcome of agonistic behaviour, as a proxy for measuring aggression in groups of pigs (Van de Weerd et la., 2006; Knox et al., 2014; Stevens et al., 2015; Galli et al., 2021). Work by Turner et al. (2006) suggested that the skin lesion count approach can be used to measure the durations of agonistic behaviours provided that differences in individual pig liveweight be accounted for. Further, Turner et al. (2006) discovered that lesions found on the anterior third of the body were a result of engagement in reciprocal fighting while lesions found on the caudal third of the body were a result of bullying. In addition, low lesion scores may indicate that the pigs successfully avoided engagement in reciprocal fights and the receipt of bullying (Turner et al., 2006).

1.5 Group Housing Management

The main behaviour observed and analyzed when grouping sows is agonistic behaviour. At mixing, aggression is the main behaviour shown as it is priority for the sows to establish their social status in the group. Sows show aggression by initiating fights in a series of head-to-head knocks or head-to-body knocks (Jensen, 1980). These aggressive behaviours can result in lameness, especially in the first three days post-mixing (Bos et al., 2016). The parameters of how behaviour affects performance of sows will now be discussed in the context of previous research regarding different group management strategies, particularly time of mixing and group dynamics.

1.5.1 Time of Mixing

The timing of grouping pregnant sows is very critical as the risk for pregnancy loss is greater during the embryonic period (0 to 35 days post insemination) than the fetal period (Peltoniemi et al., 2016). It has been well established that the risk of reproductive failure is greater for sows mixed into groups shortly after insemination and before the critical time of embryo implantation (Li & Gonyou, 2013; Knox et al., 2014; Cunha et al., 2018). More specifically, implantation, which occurs between 13 and 24 days after insemination (Kyriazakis & Whittemore, 2006), is a crucial process which determines whether or not the embryo can successfully develop into a fetus (Wang et al., 2014). As such, stress should be minimized during this critical period to allow a successful implantation without compromising litter size (Wang et al., 2014).

Li and Gonyou (2013) mixed sows 2-9 days after breeding or 35 days after breeding into groups fed with ESF and with space allowances varying from 1.9 to 2.2 m^2/sow. The sows that were mixed earlier had lower farrowing rates but fewer skin lesions before farrowing compared to the sows that were mixed later in gestation. This research indicates that early mixing can have negative impacts on sow reproductive performance (Li and Gonyou, 2013).

In a study conducted by Knox et al. (2014), reproductive performance and animal welfare were measured comparing sows mixed at different time periods after breeding. The three treatment groups that involved mixing sows were: sows mixed 3-7 days after breeding, sows mixed 13-17 days after breeding or sows mixed 35 days after breeding (Knox et al., 2014). Each group was mixed into static groups of 58 sows with a space allowance of 1.74 m^2/sow and fed with ESF. With regards to behaviour, the results showed less fights during the first 24 h after mixing for the sows mixed on day 14 compared to the other two mixed groups. Serum cortisol levels were higher in sows mixed on day 35 compared to sows housed in stalls and those mixed on day 3. In terms of production measures, results showed reduced conception rates in sows mixed 3-7 days after breeding and in sows mixed 13-17 days after breeding compared to sows mixed around day 35 after breeding and stalled sows. Farrowing rates were lower in sows mixed on day 3 compared to those mixed on day 35 and stall housed. The authors concluded that the day of mixing impacts reproductive measures as well as increasing lameness and some other measures of welfare (Knox et al., 2014).

A third study by Cunha et al. (2018), compared different mixing times for gilts. Their treatments included gilts housed in stalls, gilts grouped at seven days post-breeding and gilts grouped at 30 days post-breeding. Gilts in the group treatments were mixed into static groups of 55 per pen with a space allowance of 2.2 m^2/gilt. Cunha et al. (2018) found that mixing gilts at day seven negatively impacted the farrowing rate whereas gilts group-housed at 30-days post-insemination did not negatively impact reproductive performance. In addition, culling due to locomotor issues was found to be greater in gilts mixed earlier compared to gilts mixed later and to those housed in stalls (Cunha et al., 2018). All three of the trials above were carried out with lower-competitive ESF feed systems and thus the aggression that occurred in these studies can be presumed to be mostly due to social grouping rather than competition for feed resources. A more recent study found that mixing sows four days post-insemination into static groups of 21 sows had no negative impact on farrowing rate nor litter size compared to mixing sows at 28 days post-insemination indicating the possibility to mix sows early without impacting production (Galli et al., 2022).

In addition, research has shown that mixing sows after embryo implantation reduces the frequency of aggression and concentration of salivary cortisol (Strawford et al., 2008; Stevens et al., 2015). Strawford et al. (2008), compared sows mixed 2-9 days post-breeding to sows mixed 37-46 days post-breeding. Stevens et al. (2015), also compared pre- and post- implant mixing into groups of 85 sows with 2.3 m^2 space allowance per sow and found that sows mixed early after insemination had greater challenges associated with aggression, injuries, and stress at mixing.

Although sows would spend less time in stalls if grouped earlier, the literature suggests that mixing, especially before implantation, could result in reduced reproductive performance and would thus not be a recommended practice. Alternatively, research suggested that mixing sows directly at weaning had no negative impact on sow performance (Brown, 2015). However, the effect of time of mixing on aggression behaviour is still not fully understood and thus requires more attention.

1.5.2 Group Dynamics

Social grouping can be divided into two main methods: static and dynamic. Static grouping refers to groups that remain the same during the gestation period; no additional sows are added to the group. Dynamic grouping refers to the regular removal of sows close to farrowing and introduction of new sows, at an earlier stage of gestation, resulting in frequent changes to group composition.

Research completed on ten commercial farms in Belgium found that sows housed in static groups had lower lameness scores and decreased skin lesion prevalence (Bos et al., 2016). In this study all five farms with dynamic systems had ESF while the other five farms with static systems differed in feeding type between vario-mix feeders, ESF and free-access stalls. Group sizes also differed from 20 to 170 sows. Another study housed sows in dynamic groups of 35 sows and compared two different space allowances, 2.25 m^2/sow and 3.0 m^2/sow (Remience et al., 2008). It was concluded that sows in the pen with the higher space allowance had reduced agonistic behaviour (Remience et al., 2008). It is evident that each farm varies in housing environment which makes comparisons between farms very difficult.

Previous research comparing static to dynamic groups has shown higher incidences of lameness and skin lesions in sows housed in dynamic groups (Anil et al., 2006; Bos et al., 2016; Li & Gonyou, 2013). This result can be explained by the fact that the social hierarchy needs to be re-established every time the group changes thus increasing the risk of skin lesions and lameness. More specifically, Anil et al. (2006), compared dynamic to static grouping using an ESF feeding system and found an increase in total number of injuries as well as lower number of nonagonistic social interactions in the dynamic group and concluded that welfare was compromised in the dynamic treatments. In terms of sow production parameters, farrowing performance did not differ between the two groups (Anil et al., 2006). In contrast, a study by Pluym et al. (2011) found no difference in the welfare of sows between static or dynamic group structure based on the comparison of lameness and claw lesions in eight commercial herds. They did note however, that although welfare was comparable between the two grouping systems, the overall prevalence of lameness, 9.7%, was quite high for group housing overall (Pluym et al., 2011). In an experiment introducing five new sows to a group of ten resident sows, Krauss and Hoy (2011) found that although aggression increased upon introduction of new sows, it was only for a short period, and they concluded that no severe implications of welfare are expected. Thus, it appears that levels of aggression are increased in dynamic grouping systems but conclusions vary on whether the welfare of sows is compromised. Further studies are needed to better understand the impact of different mixing systems on sows. Having a better understanding of social behaviour and social status of sows in group housing situations will not only increase the sows' welfare but also increase productivity and thus returns to the producer.

The findings from the studies mentioned above show that mixing sows into groups will potentially compromise physical health of the sows. However, if the aggression at mixing, as well as ongoing aggression, can be properly managed to mitigate the risks, then the long-term social benefits of group housing will outweigh any minor skin lesions. The literature shows many different housing systems can potentially work well provided that management is good. However, there is a knowledge gap on how to refine management to optimize welfare and production of group housed sows (Pedersen-MacNab et al., 2019).

The extensive variability among housing systems, as well as variability with the different measures used by researchers to determine the welfare of sows, means that definitive conclusions are difficult to draw when analyzing the existing research (Salak-Johnson, 2017; Fraser, 2008). Although much has been established already regarding group housing management, further refinement is needed to identify how specific aspects of group management contribute to the welfare of sows with regards to their behaviour and performance.

1.5.3 Interaction between Group Structure and Social Status

Within a group of sows, there are both dominant and subordinate animals which makes up the social hierarchy. Based on the social status of the sow, their interaction with other sows and their experience in the group will differ. When mixing three small static groups of four sows into a larger dynamic group, O'Connell et al. (2003), found that sows with lower social status had lower body weights and higher injury scores one week after mixing. Physiologically, they found that salivary cortisol levels were not significantly affected by social status at one week after mixing (O'Connell et al., 2003). In another study analyzing social status, Roy et al. (2019) found that subordinate sows received more skin lesions due to aggression than dominant sows. They also found significantly higher salivary cortisol levels (measured at weeks 6, 10, and 14 of gestation) in the subordinate sows compared to dominant sows (Roy et al., 2019). These results suggest that the subordinate sows in the group will experience greater stress. In addition, other social measures such as parity could be related to mixing stress. Horback et al. (2021) observed that in a large dynamic pen, older sows seemed to rest in areas based on location in the pen, while younger sows seem to form associations for specific individuals in the pen. They also found that sows that rested on the slatted floor, presumably less favorable, were younger and had more severe body lesions than all older parity sows (Horback et al., 2021). Thus, social status plays a key role in the wellbeing and performance of sows housed in groups.

1.6 Conclusion

Increasing concern for animal welfare over the past 50 years has led to a strong societal push towards less restrictive housing options for animals. This has required research to be conducted to guide producers on how to best manage sows in an open, group housing environment. One of the main welfare concerns that arises with the grouping of sows is aggression at mixing associated with establishment of the social hierarchy. This agonistic behaviour causes stress and in severe cases can cause lameness and pregnancy loss. The existing literature covers studies conducted under many different designs of group housing varying in group dynamics, time of mixing, space allowance and method of feed delivery. With such a range of variables, it is difficult to identify relationships and draw conclusions as to which housing design offers the best welfare and optimizes production for the animal. It is clear, however; that both sow behaviour and performance must be analyzed to gain further understanding of the sows' welfare under different group management strategies. With the need for more refined research, the results from this study will help to further understand the effects of group housing on sow welfare and production and to advise producers on management practices in the transition to group housing. This study was part of a larger project which followed the effects of sow grouping practices and social status on piglet development.

1.7 Objectives

This study had three main objectives:

- To compare the production and behaviour of gestating sows in static and dynamic groups and the impact on sow aggression and injury;
- To compare the effects of early and late mixing on measures of reproduction;
- To study the behavioural differences between dominant and subordinate sows in static and dynamic groups.

Specific objectives include:

- Measure the production performance to determine risks and benefits of mixing sows into dynamic and static groups;
- Analyze the levels of stress to determine the impact of static versus dynamic grouping treatments on sows of different social status.

1.8 Hypotheses

In order of objectives listed above, the main hypotheses for this study include:

- Compared to static grouping, dynamic grouping will negatively impact sow productivity due to the increased number of mixing events which has the potential to cause more aggression.
- Dynamic grouping will result in greater social stress because the sows will be subjected to more mixing events than the sows in the static groups which causes a need to re-establish social hierarchies.
- Reproduction performance will be lower for early mixed sows as acute stress will occur prior to embryo implantation.

- Younger sows will be subordinate to higher parity sows and will experience greater stress, especially those in dynamic groups, as they will have lower ranks within the group.

Specific hypotheses for this study include:

Behaviour

- Aggressive behaviour will be most severe shortly after mixing and more frequent in early and dynamic mixing groups as mixing is the time of social hierarchy formation.
- Levels of stress will be higher for subordinate sows as well as for sows in dynamic treatment groups compared to dominant sows and sows in the static treatment group as these sows will endure more aggressive behaviour.

Sow Performance

- Sow condition is anticipated to stay similar for all treatment groups with the exception of low ranking/ subordinate sows who will lose condition.

2.0 THE EFFECTS OF GROUPING PRACTICES AND SOCIAL STATUS ON SOW PRODUCTION AND REPRODUCTIVE PERFORMANCE

2.1 Abstract

As the Canadian swine industry transitions gestation housing from stalls to groups, it is important to understand the impact of different grouping practices on sow performance. This study compared the effects of three grouping treatments in gestation on sow productivity and reproductive performance. Treatments included: Control (Con): sows housed in stalls for 35 days after insemination, then moved to static groups; Static (Sta): sows mixed into static groups 1-8 days after insemination; and Dynamic (Dyn): sows mixed into dynamic groups 1-8 days after insemination with monthly mixing (8-10 sows removed and replaced). Sows were housed in groups of 25 per pen in three replicates (total: 225 sows). Body weight, body condition score and backfat thickness were recorded at two timepoints: once at breeding and again when sows were moved to farrowing. Farrowing rate, litter characteristics and piglet birthweights were recorded. Statistical analysis was performed in SAS 9.4 using mixed effects models with main effects of treatment, parity and social status.

There were no treatment effects for body weight or for body condition score. There was a significant treatment by parity effect for backfat where mid-parity Dyn sows gained the most backfat over gestation while older Con sows gained the least ($p=0.049$). Farrowing rates for Con, Dyn and Sta treatments were 81%, 88% and 62%, respectively (Chi sq $p<0.001$). There were no significant treatment differences for litter characteristics; however, there was a trend for the Dyn sows to have fewer total born and fewer stillborn piglets than Con or Sta sows ($p=0.086$ and $p=0.055$, respectively). The results from this study do not indicate any productivity drawbacks to dynamic mixing, thus the results support this practice as a viable alternative for pork producers.

2.2 Introduction

The Canadian swine industry is currently transitioning housing systems for gestating sows from individual stalls to group systems in accordance with the Code of Practice for the Care and Handling of Pigs (NFACC, 2014). Group housing will allow the animals greater freedom of movement and gives sows the ability to express more natural behaviours. One drawback of group housing is that when unfamiliar sows are mixed, they form a social hierarchy through aggressive behaviour. Mixing aggression can cause considerable stress and leads to injuries, thus, aggression endured at mixing may negatively impact sow productivity (Li & Gonyou, 2013).

There is a variety of sow grouping practices that exist, varying in group dynamics and time of mixing. There are two grouping types for sows: static and dynamic. Static grouping refers to sows being mixed into a group that remains the same throughout gestation, with all animals being at the same stage of pregnancy and no new animals added to the group. Dynamic grouping refers to groups containing sows at various stages of gestation where animals are periodically added and removed from the group. Few studies exist that directly compare the performance effects of static to dynamic grouping and results are conflicting. Simmins (1993) found a lower farrowing rate in the static sows compared to the dynamic sows, 78% and 85% respectively. However, sows in the static groups had larger litter sizes and higher litter weights than the sows housed in the dynamic groups (Simmins, 1993). In contrast, Anil et al. (2006) found no differences in farrowing performance between static and dynamic groups.

Gestating sows can be mixed soon after insemination, within 1-8 days: known as early or pre-implantation mixing, or within 28-35 days: known as late or post-implantation mixing. Studies that compare time of mixing are also inconclusive as to when the best time of mixing is. Knox et al. (2014) found a reduced farrowing rate in sows mixed at 3-7 days post insemination compared to sows mixed at 35 days, while Galli et al. (2022) found no differences between mixing treatments (day 4 and day 28) in backfat thickness, farrowing rate or litter characteristics.

The effect of sow social status is an additional element of group housing that has been studied (Norring et al., 2019; Brajon et al., 2021). Both subordinate and dominant sows are highly involved in fighting at mixing; however, subordinate sows are more negatively affected than dominant sows (Brajon et al., 2021). In addition, in a competitive group environment, lower ranking sows may need extra attention (Norring et al., 2019).

Many pork producers have implemented large dynamic groups with early mixing as this combination allows the use of precision feeding offered by ESF. Although this system automates feeding and reduces feed competition, there is potential for greater aggression as with every mixing event the social hierarchy is disturbed and needs to be re-established, thus, the full impact of this practice on sow performance is not well understood (Strawford et al., 2008; Bench et al., 2013). When evaluating the benefits and drawbacks of a new housing system, the impact on production performance of the sow is an important consideration. Factors such as body weight, backfat thickness and body condition scoring are important for animal health and reproduction (Huerta et al., 2021). Reproductive performance factors such as farrowing rate, number of total born, live born, still born and mummified piglets are critical as these factors determine how successful the sow will be in producing a healthy litter of piglets and will influence the economics of production.

The aim of this study was to generate knowledge on the effects of dynamic group housing on sow production. Specifically, this study compared the effects of static and dynamic grouping on measures of production. It was hypothesized that sows in the dynamic groups would experience greater social stress compared to those in static groups and thus have reduced reproductive performance but with no difference in sow body condition. This study also compared the effects of early and late mixing on measures of reproduction. It was hypothesized that early mixing would negatively impact sow reproductive performance as the stress of mixing would be endured during the time of pregnancy recognition and prior to embryo implantation. Finally, this study aimed to determine the effects of different grouping practices on production in sows of different social status. It was hypothesized that the combined effect of social status and grouping practice would mean that subordinate sows in dynamic groups would have reduced performance in terms of body condition and litter quality.

2.3 Materials and Methods

All experimental procedures were approved by the University of Saskatchewan Animal Care Committee and Animal Research Ethics Board (AUP# 20210052) which followed guidelines of the Canadian Council on Animal Care (CCAC, 2009).

2.3.1 Housing and Treatments

The experiment took place at the Prairie Swine Centre (PSC), a swine research facility simulating commercial practices, located in Saskatoon, Saskatchewan. The sows were housed in the gestation barn using four T-shaped pens with 32 free-access stalls each (Figure 2.1). This study housed sows in groups of 25 animals and consisted of three treatments each replicated three times, for a total of 225 sows on trial (25 sows x 3 treatments x 3 replicates). The genetics of the sows were Camborough Plus, Landrace-Large White (PIC Canada, Winnipeg, MB, Canada).

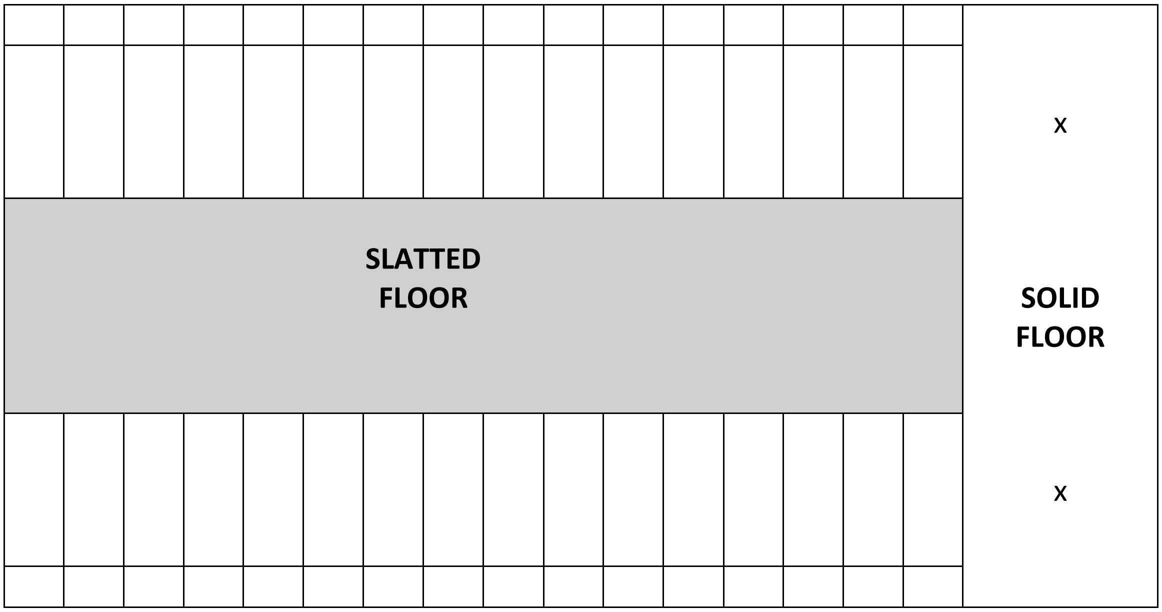


Figure 2.1 Gestation pen layout, including 32 free-access gestation stalls with slatted alley (3.0 m x 10.7 m) and solid floored 'T' area (3.8 m x 7.1 m). 'X' marks location of point source enrichments.

At weaning, sows were assigned to one of three treatments: Control (Con): sows housed in breeding stalls after insemination for 35 days and then moved to static groups; Static (Sta): sows mixed into static groups from one to eight days after insemination; Dynamic (Dyn): sows mixed into dynamic groups from one to eight days after insemination with monthly mixing events (8-10 sows removed and replaced). The protocol for mixing sows is described in Appendix A.

The free access stalls were used for the morning feeding at 7 am. One hour after feed was dropped, sows in all treatments were removed from stalls and locked out into the common loafing area of the pen until the following morning to simulate group housing. The loafing area of each pen contained two nipple drinkers, 29.7 m^2 of slatted floor (width of slat: 12.00 cm; width of gaps: 3.00 cm), and 22.3 m^2 of solid floor, giving space allowance of 2.08 m^2/sow. In addition, each pen was fitted with two point-source enrichments: cotton rope and Astro 200 toy (Easyfix, Galway, Ireland), which were suspended in the solid floor area. The trial sows were also allowed access to the stalls on the weekends to facilitate easier handling of sows by production staff. Sows were let into the stalls Friday afternoon around 3 pm and were locked out Monday morning after feeding. Any sows removed during the trial and reasons for removal (reproductive failure, lameness, or other) were recorded.

2.3.2 Sow Breeding and Selection

Following standard PSC sow management, approximately 14 sows were bred each week. Therefore, to form groups of 25 sows bred within a 7-day period, 14 sows were weaned on Monday (~29 d after farrowing) and 14 sows were weaned the following Saturday (~21 d after farrowing). Sows came into heat/were bred on different days, and groups were formed once 25 sows had been bred.

Each treatment was composed at least 8% gilts (at least 2 gilts per group of 25 animals), while numbers of other parities varied according to PSC herd distribution. Due to the limited number of sows available, study enrolment and data collection took place over a period of 14 months (August 2021 to September 2022). See Table 2.1 for parity distribution within each treatment.

Table 2.1 Parity distribution of sows by treatment (number and precent).

Treatment	Parity Group*			Total
	Young	Medium	Old	
Control	34 (46%)	20 (27%)	20 (27%)	74
Dynamic	31 (40%)	29 (37%)	18 (23%)	78
Static	31 (42%)	18 (24%)	25 (34%)	74

* Sow parities were grouped as ‘young’ (P0, P1), ‘medium’ (P2, P3) and ‘old’ (P4 and greater)

2.3.3 Diet

The diet fed to sows during the trial consisted of a typical production diet meeting NRC (National Research Council) requirements which was modified twice during the period of the study. Due to changing grain prices, in October 2021 the diet was changed from a 100% wheat-based diet to 50:50 corn:wheat diet. The diet was changed again a month later from the 50:50

corn:wheat diet to a 100% corn-based diet. In addition, the daily feed allotments were reduced at the time of the second feed change due to observations of over-conditioned sows and gilts. Although these diet changes are confounding factors for this study, they reflect the reality of production barns changing their diets to follow least-cost feed formulation. During the time of the first feed change, only sows in the first replicate of the Con treatment were in gestation. The second feed change impacted sows in the first and second replicates of the Con treatment as well as the first replicate of the Sta treatment.

Production staff regularly checked body condition scores throughout the trial and any animal that was identified as thin (BCS of ≤ 2) received one extra scoop of feed in the morning until they were no longer thin.

The use of dietary fibre as an enrichment was an additional intervention used to increase satiety in the sows and facilitate removal of sows from stalls after feeding. A water-soaked mixture of hay cubes and beet pulp (2:1 water:fibre ratio with a total of approximately 2.8 kg of dry fibre/pen/day) was provided on weekdays to sows in the solid floor area in the morning after they exited the stalls. Providing the extra source of fibre was implemented in December 2021 to facilitate moving sows out of feeding stalls and the protocol for provision can be found in Appendix B.

2.3.4 Sexual Behaviour and Return to Estrus

As a routine practice in the barn, bred sows were observed for signs of return to estrus starting on day 18 for three days (D18 to 22) (see Table 2.2 for signs of estrus). Ideally, sows were observed after feeding (~8 am); however, depending on activities in the barn, sows were observed later during the day. Estrus expression, standing behaviour and vulva appearance were observed. Any sows that showed signs of heat were recorded and were held in a stall until out of heat (approx. 2

days). Sows then returned to the group until they were culled, which was about 2 weeks before the rest of the group was ready to move to farrowing. In the Dyn treatment, not-in-pig (NIP) trial sows in the group were removed at the next mixing event and replaced with newly bred sows. In the Sta treatment, due to the high number of abortions, any open sows in the group were injected with PG600 and re-inseminated once they showed signs of heat so that they could be kept in the group to maintain space allowance.

Table 2.2 Signs of estrus for sows.

Estrus Signals	Description
Red/swollen Vulva	The vulva and surrounding tissue are enlarged and red
Discharge	A clear/white mucus discharge from the vulva
Standing Reflex	The sow stands in a rigid posture for 10 or more seconds when back pressure is applied
Upright Ears	Sow’s ears are pricked upright and held tight against the head
Approaches Boar	Sow approaches or focuses intensely on the boar
Vocalization	Sow vocalizes without any human contact, may vocalize upon observation of boar

2.3.5 Pregnancy Checks

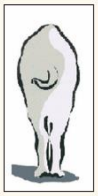
As per standard production activities, pregnancy checks by ultrasound (iMaGO.S 1411MS51, imv imaging, Bellshill, Scotland) were conducted by barn staff to confirm pregnancy of sows. Any sows that were not pregnant were recorded. Ultrasounds generally took place in W4 (D21 – D25) and W8 (D50) of gestation; however, due to staffing time constraints, pregnancy checks did not always occur on time.

2.3.6 Body Weight, Backfat Thickness and Body Condition

All sows were weighed at the time of weaning prior to being moved to breeding. Body weight was recorded a second time when sows were moved from gestation to farrowing, at around 110 days of gestation, under the same procedures.

Backfat thickness was measured within 10 days after weaning and again when sows were moved from gestation to farrowing. Backfat was taken at the P2 position, 65 mm from the dorsal mid-line at the level of the last rib, as described in Appendix C.

Body condition was scored in the breeding stalls just after the sows were weaned according to the 'Code of Practice for the Care and Handling of Pigs' (NFACC, 2014; Figure 2.2). Body condition was scored a second time in the farrowing crate on the day that the sows were moved to farrowing. Two researchers were trained to score body condition. Inter-observer agreement was calculated using the results obtained during pre-trial training observations until an >80% agreement was reached.

				
Condition score 1:	**Condition score 2:**	**Condition score 3:**	**Condition score 4:**	**Condition score 5:**
The sow is visually thin, with hips and backbone very prominent and no fat cover over hips and backbone.	The hip bones and backbone are easily felt without any pressure on the palms.	It takes firm pressure with the palm to feel the hip bones and backbone.	It is impossible to feel the bones at all even with pressure on the palm of the hands.	The sow is carrying so much fat that it is impossible to feel the hip bones and backbone even by pushing down with a single finger.

Score	Appearance	Pelvic Bones	Loin	Ribs
1	Emaciated	Very prominent. Deep cavity around tail head	Vertebrae are prominent and sharp. Very narrow loin. Hollow flank.	Individual ribs are very prominent.
2	Thin	Obvious with slight cover.	Narrow loin. Flank rather hollow. Slight cover on spine, but prominent vertebrae.	Rib cage less apparent but individual ribs easily detected with slight pressure.
3	Ideal	Covered but felt with pressure.	Spine covered and rounded.	Ribs are covered but can be felt with pressure.
4	Fat	Only felt with firm pressure. No cavity around tail.	Difficult to feel vertebrae. Flank filled.	Rib cage not visible and difficult to feel.
5	Obese	Impossible to feel and huge fat deposits (hanging skin and fat).	Thick fat cover, impossible to feel bones. Flank full and rounded.	Thick fat cover, not possible to feel ribs.

Figure 2.2 Body condition scoring system defined in 'Code of Practice for the Care and Handling of Pigs' (NFACC, 2014).

2.3.7 Reproductive Performance

Reproductive performance was measured by farrowing rate which was calculated by dividing the number of sows that farrowed by the total number of sows bred. The number of sows farrowed included the sows that were taken off trial and removed from the pen due to lameness but which still farrowed. In addition, litter characteristics including litter size, number of piglets born alive, stillborns, and mummies were recorded. To determine if a stillborn was truly stillborn, a lung flotation test was performed using the techniques outlined in Bhattarai et al. (2018). Individual piglet birth weights, including stillborns, were recorded within 24 hours of birth and summed for a total litter weight.

2.3.8 Determination of Social Status

To determine the social status of sows in the group, a feed competition test was performed similar to the methodology used by Roy et al., 2019. This test was applied during three days of the first week of group formation (D3 to D5) and for three days mid gestation. The test took place between 12:30 and 1:30 pm, with staff present and had a total duration of 10 minutes (or 600 seconds). On the first and second days of the test, half the amount of feed, 4 kg divided into two pails, was placed in the pen to habituate the sows to the test routine. On the third day, sows were individually marked with livestock crayon and the full amount of feed, 8 kg divided into two pails, was placed and the pen was video recorded. Data were continuously recorded in Cowlog (Hänninen & Pastell, 2009) by two researchers and included recording the time each sow spent at (snout down at feed line) and in proximity (snout and face directed towards the feed line) to the feed line in addition to the frequency of fights won, lost and drawn, and the number of times she performed and received aggression.

To obtain a numerical value for social status, a Dominance Index Value (DIV) was calculated by dividing the time a sow spent at the feed line by the total time of the test (600 seconds). If the values for these calculated numbers was between 0 and 0.33 the sow was assigned a social rank of subordinate, if the value was between 0.34 and 0.73, the sow was assigned an intermediate social rank and if the value was between 0.74 and 1, the sow was assigned dominant as the social rank. For the final social rank status, an average of both feed competition tests was used. If the sow was only present in the first feed competition test, social status was based on the results of the first feed competition test only.

2.3.9 Statistical Analysis

All statistical analysis was performed using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA) with sow as the experimental unit. Sow parities were grouped as ‘young’ (P0, P1), ‘medium’ (P2, P3) and ‘old’ (P4 and greater) for all statistical analyses except correlations where the actual parity was used (Brown et al, 2009). Spearman correlations were performed for bodyweight, backfat, and body condition with actual parity and social status as identified by the DIV. For continuous data, all residuals from the model were tested for normality using the Shapiro-Wilk statistic. Two outliers were removed in the analysis of change in backfat and one outlier was removed in the analysis of litter weight. A mixed model ANOVA (PROC MIXED) was used to analyse the change in bodyweight and backfat as well as litter weight. Main effects were treatment, parity and social status with replicate as the random effect. Interactions included in the model were treatment by parity and treatment by social status. In the model analysing litter weight, total born was used as a covariate. Interactions that were not significant ($p>0.05$) were removed from the final model. Body condition scores and other litter characteristics (i.e. total born, live, still and mummified) were analysed using a glimmix model (PROC GLIMMIX) with Poisson distribution using the same main effects as above. One outlier was removed prior to analysis of total born. The least-square means (LSMEANS) of fixed effects with Tukey’s adjustment were used to account for multiple comparisons. Any results that had a p-value of $p<0.05$ were considered significant and a trend was identified for results with a p-value of $p<0.10$.

2.4 Results

Based on the feed competition test results, each sow was assigned a social rank as either dominant, intermediate or subordinate. The distribution of social status for each treatment replicate is presented in Table 2.3.

Table 2.3. Distribution of social status by treatment replicate (Rep).

Grouping Practice*	Rep	Number of Sows of each Social Status		
		Subordinate	Intermediate	Dominant
Control	1	9	14	2
	2	11	10	3
	3	13	8	4
Dynamic	1	13	6	5
	2	14	7	4
	3	12	8	4
Static	1	6	13	4
	2	11	11	3
	3	12	11	2

* Control: 25 sows mixed at ~35 days after breeding into static groups; Dynamic: 25 sows mixed early after breeding into a dynamic group; Static: 25 sows mixed early after breeding into a static group.

2.4.1 Sow Body Weight, Backfat Thickness and Body Condition

Initial body weights (in kg) represented as mean ±SD by treatment were: Con: 214.92 ±40.71; Dyn: 219.52 ±41.50; Sta: 225.87 ±42.51 (p=0.61). Initial backfat thickness measurements (in mm) represented as mean ±SD by treatment were: Con: 10.81 ±2.74; Dyn: 10.39 ±3.03; Sta: 10.62 ±2.88 (p=0.82). Average initial body condition scores ±SD by treatment were: Con: 3.01 ±0.42; Dyn: 3.29 ±0.65; Sta: 3.16 ±0.60 (p=0.62).

The change in sow body condition factors over gestation by grouping treatment (means ±SD) are presented in Table 2.4. Sow grouping treatment and social status did not have a significant effect on changes in body weight, backfat thickness or BCS. However, there was a significant treatment by parity interaction for backfat, with mid-parity Dyn sows gaining the most backfat and older Con sows gaining the least backfat (p=0.0498). In addition, parity had a significant effect in the change on body weight where younger sows (gilts and P1) gained the most body weight over gestation and older parities (≥P4) gained the least.

Table 2.4 Change (final-initial) in sow condition factors by grouping treatment*.

Item	Treatment (TRT) (mean ±SD)			Pooled SEM				
	Control	Dynamic	Static		TRT	SS**	Parity	TRT x Parity
n	55	65	43					
Body weight (kg)	36.33 ±23.04	42.75 ±23.41	35.20 ±25.83	5.38	0.629	0.135	**<0.001**	NS***
Backfat (mm)	0.67 ±1.91	1.79 ±1.87	0.49 ±1.32	0.51	0.159	NS	0.185	**0.050**
BCS	0.24 ±0.64	0.26 ±0.64	0.07 ±0.67	0.08	0.879	0.803	0.177	NS

* Control: 25 sows mixed at ~35 days after breeding into static groups; Dynamic: 25 sows mixed early after breeding into a dynamic group; Static: 25 sows mixed early after breeding into a static group.

**Social status: was determined for sows in each group as Dom- dominant, Int- intermediate, Sub- subordinate based on feed access in two feed competition tests

***NS: not significant, variable was removed from final model

Correlations between sow body condition factors and actual parity and DIV (or social status) are summarized in Table 2.5. All factors except for change in backfat had a significant correlation with parity. There was a significant positive correlation between DIV and final weight indicating that more dominant sows were heavier at the end of gestation (p=0.006). There was a trend for a positive correlation between initial body weight and social status (p=0.068) as well as a trend for a negative correlation between initial BCS and social status (p=0.088).

Table 2.5 Spearman correlations (r and P values) between sow parity and social status (DIV) and body weight, backfat and body condition scores. Significant correlations (p<0.05) are indicated in bold.

		Actual Parity		DIV	
		r	p-value	r	p-value
Body Weight	Initial	**0.890**	**<0.001**	0.135	0.068
	Final	**0.749**	**<0.001**	**0.215**	**0.006**
	Change (Final- Initial)	**-0.751**	**<0.001**	-0.125	0.112
Backfat Thickness	Initial	**-0.298**	**<0.001**	-0.055	0.455
	Final	**-0.336**	**<0.001**	-0.019	0.810
	Change (Final- Initial)	0.032	0.688	0.027	0.739
BCS	Initial	**-0.198**	**0.003**	-0.126	0.088
	Final	**-0.340**	**<0.001**	-0.125	0.112
	Change (Final- Initial)	**-0.261**	**<0.001**	-0.024	0.765

2.4.2 Sow Reproductive Performance

Descriptive information of sows in each treatment is presented in Table 2.6. Farrowing rates for the Con, Dyn and Sta treatments were 81%, 88% and 62%, respectively.

Table 2.6 Descriptive information of sows on trial.

Item	Treatments		
	Control	Dynamic	Static
Allocated to treatment	74	78	74
Days pregnant at mixing (median, range)	34, 26-38	2, 1-7	6, 0-11
Number of sows that farrowed (including sows that were removed from study)	60	69	46
% Farrowed	81.08	88.46	62.16
Total removed from study	19	13	30
Abortion	5	2	6
Lameness	4	3	2
Died	2	1	1
Other	2	4	2
NIP*	6	3	19
Treated for lameness but not removed from study**	5	7	4

*NIP (Not-in-pig): sows that were identified as not pregnant due to reabsorption of fetus, abortion or breeding issues. However, in the case of the Control treatment, all sows were confirmed pregnant prior to mixing thus the reasons for NIP are missed abortions. NIPs were kept in the group to maintain group size at a minimum of 21 sows per pen until about 2 weeks prior to farrowing.

**Any sows identified as having lameness score of ≥ 2 were treated with 5 cc of meloxicam and evaluated the next day to see if they needed to be treated a second day.

The litter characteristic results for the three grouping treatments are presented in Table 2.7. Treatment and social status did not have any significant effects on the litter characteristics measured. There were trends for Dyn sows to have lower number of total born, live born and still born piglets ($p=0.09$, $p=0.09$ and $p=0.06$, respectively). Parity had a significant effect on the number of stillborn piglets where younger sows had fewer stillborns than mid-parity and older parity sows ($p<0.01$).

Table 2.7 Production results (per litter) for gestating sows managed in three group housing systems* (mean ±SD).

Item	Grouping Treatment (TRT)			Pooled SEM	p values		
	Control	Dynamic	Static		TRT	SS**	Parity
n	54	65	43				
Total Born	17.33 ±3.24	16.09 ±3.37	17.71 ±2.89	0.60	0.086	0.973	0.226
Live Born	15.25 ±3.13	14.51 ±3.16	16.05 ±2.94	1.68	0.087	0.555	0.596
Still Born	1.35 ±1.84	0.94 ±1.42	1.35 ±1.53	0.15	0.055	0.709	**<0.001**
Mummies	0.73 ±1.04	0.48 ±0.79	0.58 ±0.76	0.12	0.338	0.205	0.188
Litter Weight (kg)	23.32 ±3.91	23.00 ±4.59	24.03 ±3.74	0.56	0.166	0.453	0.135

*Grouping treatment (TRT): Static- 25 sows mixed early after breeding into a static group, Dynamic- 25 sows mixed early after breeding into dynamic groups, Control- 25 sows mixed at ~35 days after breeding into static groups.

**Social status (SS): was determined for sows in each group as Dom- dominant, Int- intermediate, Sub- subordinate based on feed access in two feed competition tests.

2.5 Discussion

2.5.1 Comparing Static and Dynamic Grouping

In the current study, there was no effect of grouping treatment on the change in body weight, backfat thickness or BCS. These results suggest that sows were able to maintain body condition regardless of the grouping system they were housed in. Other studies comparing sow production performance in dynamic and static groups also found no significant differences for body weight and backfat change over gestation (Anil et al., 2006; Galli et al., 2022).

In terms of reproductive performance, Dyn sows had the highest farrowing rate while Sta sows had the lowest. It was hypothesized that the Dyn sows would perform more poorly in terms of reproductive performance; however, the results indicate no repercussions on reproductive performance of sows housed in dynamic groups. In contrast, other research found no significant differences in farrowing rate when comparing static and dynamic groups which were both mixed early in gestation (Anil et al. 2006). In the study conducted by Anil et al., (2006) all sows were fed using an ESF and sows in the dynamic treatment were housed in a large group of 98 sows and mixed every two weeks, while sows in their static treatment were housed in groups varying from 23 to 31 sows. These differences in protocol between the two studies could explain why Anil et al. (2006) found no differences in farrowing rate. In the current study, Dyn sows tended to have fewer total born, live born and still born piglets indicating that grouping treatment may have a slight influence on litter quality. In contrast, Simmins (1993), comparing small groups of static sows (12 per group) and dynamic sows (18 per group), found larger litter sizes and higher birth weights in static grouped sows compared to dynamic grouped sows. Other studies, each with different group management, found no significant differences in litter characteristics (Knox et al., 2014; Stevens et al., 2015; Anil et al., 2006; Pierdon and Parsons, 2018).

2.5.2 Comparing Early and Late Mixing

In the current study, Con sows were mixed later in gestation while Dyn and Sta sows were mixed early in gestation. There were no significant differences found in terms of body weight, backfat thickness or BCS when comparing early and late mixed groups. Stevens et al. (2015) also found no significance in change in body weight or backfat between treatments when comparing early and late mixing into static groups of 85 sows.

The current study found farrowing rates of 81%, 88% and 62% for Con, Dyn and Sta treatments respectively. When comparing the Dyn and Con treatments, Dyn sows had a higher farrowing rate than did the Con sows which indicates that mixing early in gestation had no negative consequence on farrowing rate. In contrast, when comparing the Sta and Con treatments, Sta sows had an astonishingly lower farrowing rate than did Con sows which indicates that early mixing may have a negative impact on reproductive performance. Similar to the static group in the current study, when comparing early and late mixing in static groups of 58, Knox et al. (2014) discovered lower farrowing rates (82.8%) for the early mixed group (D3) compared to a farrowing rate of 90.5% for the later mixed group (D35). However, it must be noted that the early mixed group in the study conducted by Knox et al. (2014) still outperformed the Con sows in the current study in terms of farrowing rate. Stevens et al. (2015) found no differences in farrowing rate when comparing early (within 1 week post insemination) vs. late (around day 35) mixed sows. A recent study found no impact on farrowing rate when mixing sows into static groups of 21 sows per pen when mixed at 4 days post-insemination compared to mixing sows at 28 days post-insemination, 84% and 81% respectively (Galli et al., 2022). Thus, early mixing of sows, while maintaining performance, is possible but the full effects of time of mixing on sow performance remains unclear.

2.5.3 Combined Effects of Social Status and Grouping Practice

The current study hypothesized that social status would have an effect on the change in body condition of the sow, especially subordinate sows in dynamic groups which would lose body condition. The results indicated no effect of social status on changes in body condition. Although grouping practice had no effect on body condition, this study found that as social status increased, final body weight increased while body condition score decreased. This indicates that at the end of gestation, the sows with higher body weights and lower BCS's, were more dominant in the group. This correlation confirms the finding of Brajon et al. (2021) where dominant sows weighed more at farrowing that subordinate sows. Correlations between parity and body weight and parity and BCS, indicate that sows of higher parity were heavier and had a lower BCS. Although these correlations seem to suggest that sows of higher parity were more dominant in the group, the correlation between parity and DIV indicate that there is no significant correlation between the two (r=0.085 and p=0.252). Work by Norring et al. (2019) shows that heavier animals had more of an advantage in winning fights and they suggested that live weight could be used as a proxy indicator for social status. Further, the authors noted that in mixed parity groups, sows with lower body condition scores may need special attention when housed in a competitive group environment (Norring et al., 2019).

2.5.4 Weaknesses

As this study was performed in a small sow herd, there were limited number of opportunities to form treatment groups. As a result, the length of the study ran over a period of 14 months, with some treatments represented differently within each season, which may have influenced the productivity of sows on trial. Although treatments were distributed equally across the year as evenly as possible, seasonal changes might have had an effect on the reproductive performance with the possibility for reduced performance for sows enrolled into the study during the change from summer to fall as the photoperiod shortens. During the first few months of the trial, two feed changes occurred which may have impacted the body conformation of sows. It is also important to note that during this trial, sows that were observed as thin (those that had a BCS of ≤ 2) were given extra feed until they had gained weight to a BCS of 3. However, this is standard practice for maintaining sow body condition in free-access stall systems where all feed stations provide the same amount of feed.

Another complication of this study was that unlike the Con sows, sows in Sta and Dyn treatments were not confirmed pregnant before being mixed into the group. Thus, sows in Sta and Dyn groups that were found to be NIP, may have never conceived to begin with. In addition, to form static groups, sows from two consecutive weaning weeks were combined which increased the days pregnant at mixing and thus the stress of mixing occurred closer to the critical period of embryo implantation.

2.6 Conclusion

Contrary to the original hypothesis that sows in a dynamic group would have reduced reproductive performance, the lack of change in body condition and high farrowing rate for sows housed in a dynamic group indicate that regular mixing of sows is a viable grouping option. Mixing sows early in gestation had contradicting results with static sows performing poorly and dynamic sows performing better, which indicates that there is more influencing reproductive performance than simply time of mixing. Finally, there was no significant effect of social status on body condition or litter characteristics, thus, even subordinate sows in the group were able to perform under the management system used in this study.

3.0 THE EFFECTS OF GROUPING PRACTICES AND SOCIAL STATUS ON SOW BEHAVIOUR, PHYSIOLOGY AND PERFORMANCE

3.1 Abstract

As the Canadian swine industry transitions sow gestation housing from stalls to groups, it is important to understand the impact of different grouping practices on sow welfare. This study compared the effects of three grouping treatments in gestation on sow aggression. Treatments included: Control (Con): sows housed in stalls for 35 days after insemination, then moved to static groups; Static (Sta): sows mixed into static groups 1-8 days after insemination; and Dynamic (Dyn): sows mixed into dynamic groups 1-8 days after insemination with monthly mixing (8-10 sows removed and replaced). Mixed parity sows and gilts were housed in groups of 25 per pen in three replicates (total: 225 sows). On the day of mixing, sow behaviour was video recorded for measurement of reciprocal and one-sided aggression. Lesions on the front, middle and hind regions and lameness were scored before and after mixing, at ~day 63 of gestation, ~day 91 of gestation, and on the day of moving to farrowing. Hair samples were collected at 7 and 12 weeks of gestation and analysed for cortisol content. Statistical analysis was performed in SAS 9.4 using mixed effects models and Chi-square analysis.

At mixing, Sta sows had a higher frequency of reciprocal fighting in the first half hour (Chi-sq p-value <0.001), than did Con or Dyn sows. However, during the 24 hrs following mixing, sows in the Con treatment received more lesions in the middle and hind regions and in total than did Sta or Dyn sows. Total mixing lesion means ±SEM were as follows: Con: 11.71 ±0.46; Dyn: 8.69 ±0.40; Sta: 9.09 ±0.41 ($p<0.001$). Lesion scores decreased significantly over time in all groups. Throughout gestation, Dyn sows had a higher incidence of lameness and had higher lesions overall than both Con and Sta sows ($p=0.046$ and $p<0.001$, respectively). Treatment had no effect on hair cortisol concentrations but at both timepoints, young sows had the highest cortisol

concentration while mid parity sows had the lowest cortisol concentration ($p=0.04$ and $p<0.01$, respectively).

In conclusion, dynamic mixing of sows appeared to moderate the intensity of aggression at mixing as Con and Sta sows had more lesions and fought more at mixing, respectively. Meanwhile, Dyn sows had more lesions overall during gestation and increased lameness, suggesting their welfare was poorer, although the results were not severe enough to impact reproductive performance. Thus, although sows in dynamic groups appeared to have lower acute stress at mixing, they may experience greater chronic stress throughout gestation.

3.2 Introduction

Over recent years, livestock industries have been working to improve the housing conditions of animals. For gestating sows specifically, the Code of Practice for the Care and Handling of Pigs encourages pork producers to phase out gestation stalls in favour of group housing with a proposed deadline of 2024 (NFACC 2014). It has been well established that when sows are mixed into a group, they perform agonistic behaviour resulting in the formation of a social hierarchy (Arey, 1999). This aggression can lead to injuries such as skin lesions and lameness which negatively impact sow welfare. Mixing aggression and ongoing aggression throughout gestation are sources of acute stress and may even be a source of chronic stress for the sow (Lagoda et al., 2021).

A variety of sow grouping practices exist, varying in grouping dynamics and time of mixing. There are two grouping types for sows: static and dynamic. Static grouping refers to sows being mixed into a group that remains the same throughout gestation, with all animals being at the same stage of gestation and no new animals added to the group. Dynamic grouping refers to groups containing sows at various stages of gestation where animals are periodically added and removed from the group. Few studies exist that directly compare the welfare consequences of static and dynamic grouping and those that do show conflicting results. Anil et al. (2006) found that sows housed in dynamic groups had significantly higher total injury scores than sows housed in static or twice-mixed groups. In contrast, Strawford et al. (2008) found no differences in injury scores when comparing static and dynamic groups.

Gestating sows can be mixed soon after insemination, within 1-8 days: known as early or pre-implantation mixing, or within 28-35 days: known as late or post-implantation mixing. Studies that compare time of mixing are also inconclusive as to when the best time of mixing is in terms of animal welfare. Knox et al. (2014) found that sows mixed 35 days post-insemination had higher serum cortisol levels at three days post mixing compared to sows housed in individual stalls and sows mixed at 3 days. Stevens et al. (2015) found mixing sows later in gestation resulted in lower saliva cortisol concentrations (sampled on the day of mixing) and reduced frequency of aggressive behaviour. A more recent study found no difference in salivary cortisol concentrations or the number of fresh injuries on the day of mixing between early and late mixed sows (Galli et al., 2022). Cortisol extracted from hair, a minimally invasive procedure, has also been used to evaluate stress in sows over a longer period of time (Bacci et al., 2014; Everding et al., 2021).

The effect of social status of sows is an additional element of group housing that has been studied (Norring et al., 2019; Brajon et al., 2021). Both subordinate and dominant sows are highly involved in fighting at mixing; however, subordinate sows are more negatively affected than dominant sows (Brajon et al., 2021). In addition, Brajon et al., (2021) found that sows that lost all fights they were involved in, and those that avoided fights, had the highest body lesion scores at day 26 and day 84 post- mixing. Norring et al. (2019) similarly noted that submissive sows may need more attention in grouping systems where competition for resources is higher.

The method of grouping and time of mixing have impacts on sow aggression. Dynamic mixing has the potential to increase or prolong aggression (Krauss and Hoy, 2011) as repeated mixing events cause a reoccurring disruption of the social hierarchy which needs to be re-established with each introduction of new sows (Brajon et al., 2021). With many producers opting for dynamic grouping with early mixing, it is important to understand the impact of this management practice. The full effects of dynamic mixing are still poorly understood and thus require more study.

The aim of this study was to generate knowledge on the effects of dynamic group housing on measures of sow welfare. Specifically, this study compared the behaviour of sows in static and dynamic groups and assessed the impact on sow aggression and injury. It was hypothesized that dynamic grouping would result in greater social stress due to repeated mixing and re-establishment of the social hierarchy. This study also studied the behavioural differences between dominant and subordinate sows in static and dynamic groups. It was hypothesized that the younger sows would be subordinate to higher parity sows, and that subordinates would experience greater social stress, especially those in the dynamic groups.

3.3 Materials and Methods

All experimental procedures were approved by the University of Saskatchewan Animal Care Committee and Animal Research Ethics Board (AUP# 20210052) which followed guidelines of the Canadian Council on Animal Care (CCAC, 2009).

3.3.1 Housing and Treatments

This experiment took place at the Prairie Swine Centre (PSC), a swine research facility simulating commercial practices, located in Saskatoon, Saskatchewan. The sows were housed in four T-shaped gestation pens each with 32 free-access stalls (Chpt 2, Figure 1). The trial consisted of three treatments, each of which was replicated three times and housed sows in groups of 25 animals per pen, for a total of 225 sows on trial. The genetics of the sows were Camborough Plus, Landrace-Large White (PIC Canada, Winnipeg, MB, Canada).

At weaning, sows were assigned to one of three treatments: Control (Con): sows housed in breeding stalls after insemination for 35 days and then mixed into static groups; Static (Sta): sows mixed into static groups from one to eight days after insemination; Dynamic (Dyn): sows mixed into dynamic groups from one to eight days after insemination with monthly mixing events (8-10 sows removed and replaced). The detailed protocol for mixing sows is described in Appendix A.

Sows were fed in the free-access stalls. One hour after feed was dropped, sows in all treatments were removed from stalls and locked out into the common loafing area of the pen until the following morning to simulate group housing. The loafing area of each pen included 29.7 m^2 of slatted floor (width of slat: 12.00 cm; width of gaps: 3.00 cm), and 22.3 m^2 of solid floor, giving space allowance of 2.08 m^2/sow. In addition, each pen was equipped with two nipple drinkers and fitted with two point-source enrichments: cotton rope and Astro 200 toy (Easyfix, Galway, Ireland), which were suspended in the solid floor area. On weekends, the trial sows were allowed access to the stalls to facilitate easier handling of sows by production staff. Sows were let into the stalls around 3 pm Friday afternoons and were locked out of the stalls Monday morning after feeding. Any sows removed during the trial and reasons for removal (reproductive failure, lameness, or other) were recorded.

3.3.2 Sow Breeding and Selection

Following standard PSC breeding protocols, approximately 14 sows were bred each week. Therefore, to form groups of 25 sows bred within a week, 14 sows were weaned on Monday (~29 d after farrowing) and 14 sows were weaned the following Saturday (~21 d after farrowing). Sows came into heat and were bred on different days, and groups were formed once 25 sows had been bred.

Each treatment was composed of at least 2 gilts per group of 25 animals, while numbers of other parities varied according to the herd distribution of PSC. See Table 2.1 for parity distribution within each treatment. Due to the limited number of sows available, study enrolment and data collection took place over a period of 14 months (August 2021 to September 2022).

3.3.3 Determination of Social Status

Social status for each sow was determined by two feed competition tests as described in chapter 2, section 2.3.8. Using these results, the DIV was calculated by dividing the time a sow spent at the feed line by the total time of 600 seconds. If the DIV was between 0 and 0.33 the sow was assigned a social rank of subordinate, if the value was between 0.34 and 0.73, the sow was assigned a social rank of intermediate and if the value was between 0.74 and 1, the sow was assigned dominant as the social rank. For the final social rank status, an average of values from both feed competition tests was used. If the sow was only present in the first feed competition test, social status was based on the results of the first feed competition test only.

3.3.4 Mixing Aggression

On the day of mixing, cameras were placed in the gestation room to record 5 h of sows' activities (~900 to 1400 h) for each treatment replicate. All sows were crayon marked for individual identification. Aggressive behaviour during the first half hour (30 min) was transcribed from videos during replay using one minute scan sampling, by a single observer according to the ethogram described in Table 3.1.

Table 3.1 Ethogram of aggressive behaviours at mixing.

Aggression	Description of Behavior
Reciprocal fight	Reciprocal acts of aggression where each opponent bites or gives a head knock at least once. Prescence or absence of bouts* recorded.
One-sided aggression	Sow knocks, snaps and/or bites another sow, without the other sow retaliating within 5 seconds.

*****One 'bout' of aggression was defined as two animals engaged in aggression (series of HH and HB interactions) with interruptions of 10 s or less.

3.3.5 Skin Lesion Scores and Lameness

Skin lesions were evaluated in each replicate within 24 hours of mixing, 24 hours after mixing and on days 63 and 91 of gestation as well as on the day of moving to farrowing. The evaluation of skin lesions occurred after the morning feedings, as sows were individually moved out of the stalls. To evaluate injuries, the following criteria based on the Welfare Quality® protocol for pigs (Welfare Quality®, 2009) and test observations at the barn were followed:

- Observers will try to keep a distance of 0.5 m from the sow for evaluations
- Sows need to be standing up and out of the stall for evaluations

Lesions can be:

- Scratches (surface penetration, the skin is not completely open apart)
- Wounds (muscle penetration with blood and layers)
- Only red fresh and swollen lesions count

- If lesions present a continuous line, they count as 1 lesion
- If two scratches are placed next to each other, coincide in more than half of their length and have the same direction and angle, they are considered parallel scratches. Two parallel scratches with up to 0.5 cm space between them count as 1 lesion.
- If a lesion is placed in two regions, it will be counted as part of the region where the majority of the lesion is observed.

Skin injury scores were assigned as indicated in Table 3.2. A separate score for five body regions was applied: 1. Head, neck, front leg and shoulder; 2. Back, side and udder; 3. Rump and hind leg; 4. Ears; and 5. Tail. Regions 1 and 2 were separated by the line of the shoulder, region 2 and 3 were separated by the line of the hind legs. For regions 1 – 3, a score was recorded for both the left and right side of the body (Figure 3.1).

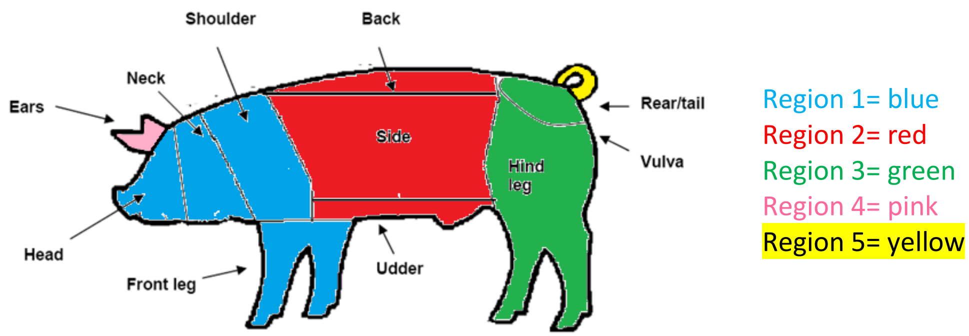


Figure 3.1 Body regions for skin lesion scoring.

Table 3.2 Skin lesions scoring system.

Point Scale Level	Description
0	No injuries
1	Less than 5 superficial injuries
2	5-10 superficial injuries and/or less than 3 deep wounds
3	More than 10 superficial injuries and/or more than 3 deep wounds

Lameness was evaluated in all sows as they were moved from weaning to breeding and again at the end of gestation when they were moved from gestation to farrowing. Additionally, sows in all treatments were evaluated for lameness on the same observation days as skin lesions; namely, on days 63 and 91 of gestation as well as on the day of moving to farrowing. On evaluation days, lameness of sows was scored after the morning feedings, as sows were moved out of the stalls one by one and used a visual point scale based on the Zinpro FeetFirst© scoring system (Table 3.3).

Table 3.3 Lameness scoring based on the Zinpro FeetFirst© scoring system.

Point Score Level	Description
0	Sow moves easily with little inducement, and she is comfortable on all four feet
1	Sow moves relatively easily but visible signs of lameness are apparent in at least one leg, although it may be difficult to determine which leg is causing the lameness
2	An abnormal gait is observed, lameness could be observed in one or more limbs, the sows may exhibit compensatory behaviours such as dipping and raising her head in time to foot falls and arching her back
3	An abnormal gait is observed, and the affected limb(s) are able to be identified, the sow may be reluctant to bear weight on the affected limb and will avoid using it, sow is reluctant to move, and it is difficult to move her from place to place in the barn

3.3.6 Hair Cortisol

Hair samples from all sows were taken from the loin part of the dorsolumbar region in a maximum area of 100 cm^2 (10 cm x 10 cm) on the left side (standing behind) of the sow. Sample collection occurred between 8-10 am after the morning feeding. Shaving occurred at three time points: ~ week 2 of gestation: hair sample discarded.

~ week 7 of gestation: 1st hair sample collected.

~ week 12 of gestation: 2nd hair sample collected.

Hair was collected onto a piece of tinfoil by shaving close to the skin with electric clippers which were cleaned with a brush between sows. Once shaved, hair was stored at room temperature inside paper envelopes until analysis. Sample analysis was performed on a subsample of samples using an ELISA kit (Salimetrics® ELISA kit, Carlsbad, CA, USA) and according to the procedures described in Pollock et al. (2021). Briefly, hair samples were weighed, washed (using methanol as the wash solvent), dried, ground into a fine powder, and weighed again before extraction.

3.3.7 Statistical Analysis

All statistical analysis was performed using SAS 9.4 (SAS Institute, Inc., Cary, NC, USA) with sow as the experimental unit. Sow parities were grouped as 'young' (P0, P1), 'medium' (P2, P3) and 'old' (P4 and greater) for all statistical analyses (Brown et al., 2009). Spearman correlations were performed between lesion scores at different time periods and litter characteristics. The frequency of reciprocal and one-sided fights that occurred at mixing was analysed using a Chi-square test (PROC FREQ). For the change in lesions at mixing, a PROC GLIMMIX model was used with Poisson distribution with main effects of treatment, parity and social status. Scores for the left and right regions were summed for the front, middle and hind regions prior to analysis.

The total overall lesion score included ear and tail lesion scores. For ongoing lesions (measured at four stages), a repeated-measures analysis of variance (ANOVA) (PROC GLIMMIX) with main effects of treatment, parity, and social status was performed with Poisson distribution. Lameness was reported for a sow if a score ≥1 was observed at any assessment point. The incidence of lame sows across treatment groups was analysed by Chi-Square test (PROC FREQ). Cortisol concentrations at the two timepoints were analysed separately. The raw data was not normally distributed and was transformed using a log transformation (log(n+1)) and analysed using a mixed model (PROC MIXED) with main effects of treatment, parity and social status. Interactions of treatment by parity and treatment by social status were tested but were not significant ($p>0.20$) and were removed from the final model. Residuals from the model were tested for normality using Shapiro-Wilk statistic. The least-square means (LSMEANS) of fixed effects with Tukey's adjustment were used to account for multiple comparisons. Any results with p-values of <0.05 were considered significant and results with $p<0.10$ were considered a trend.

3.4 Results

3.4.1 Mixing Aggression

The percent of time periods where aggression was observed in the first half hour of mixing is presented in Table 3.4. There was a significant difference between grouping treatments for reciprocal fighting, with sows in the Sta groups spending more time fighting than Con or Dyn sows ($p<0.01$). There were no significant differences in one-sided aggression between treatments ($p=0.22$).

Table 3.4 Aggression* observed during the first half hour of mixing.

	Control (%)	Dynamic (%)	Static (%)	Chi-Square p-value
		Reciprocal Fighting		
Fight	11.67	10.37	36.67	<0.01
No Fight	88.33	89.63	63.33	
		One-Sided Aggression		
Fight	22.22	28.33	24.44	0.22
No Fight	77.78	71.67	75.56	

*Percent (%) of observations where aggression (reciprocal or one-sided) was observed with scan sampling every minute for 30 minutes following mixing.

3.4.2 Change in Skin Lesions at Mixing

There was a significant treatment effect for the increase in lesion scores at mixing in the mid and hind regions and for total lesions overall, with Con sows having more lesions at mixing than Sta or Dyn (Fig. 3.2). No differences between treatments were found for the front body region of the sow. Numerically, the highest number of lesions was found on the front and the lowest number of lesions on the hind of the sow. A summary of results for the increase in lesions at mixing is presented Figure 3.2. A significant interaction between grouping treatment and social status was found for the total change in lesions at mixing. Within each treatment, social status did not affect the increase in lesions at mixing (Figure 3.3). However, dominant and intermediate Con sows had a higher increase in lesions at mixing than dominant and intermediate Dyn sows and than intermediate and subordinate Sta sows (Figure 3.3). In addition, social status had a significant effect in Con groups where dominant and intermediate sows had more lesions than subordinate sows. Total change in lesions means before and after mixing ±SEM for Con sows by social status were: dominant: 13.33 ±1.22; intermediate: 11.94 ±0.61; and subordinate: 10.18 ±0.56 (Tukey p-value for intermediate Con sows vs subordinate Con sows: p=0.035). There was no effect of social status for Dyn and Sta groups.

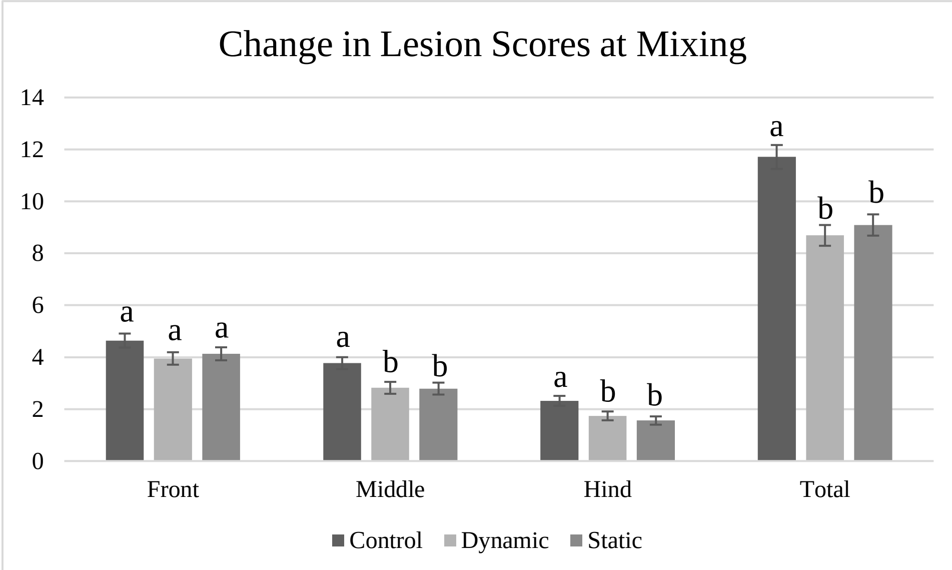


Figure 3.2 LS Means (±SEM) for the change in lesion scores at mixing for Control, Dynamic and Static sow groups. Difference superscripts (a,b) within a region (Front, Middle, Hind, Total) denotes statistical significance ($p<0.05$).

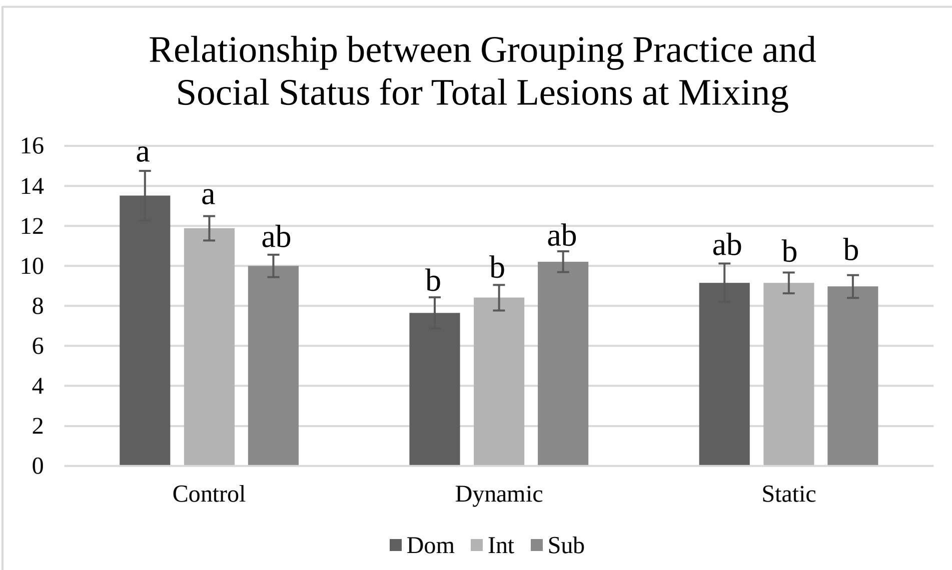


Figure 3.3 LS Means (±SEM) for the change in total lesion scores at mixing for Control, Dynamic and Static sow groups by social status. Difference superscripts (a,b) denotes statistical significance ($p<0.05$).

3.4.3 Skin Lesions throughout Gestation

The detailed results for total lesions recorded at four time points during gestation are presented in Table 3.5 and show that the number of sows on trial (n) decreased over the course of gestation.

At timepoint 1 (T1: 24 hours after mixing), Con sows had higher lesion scores than Dyn ($p=0.0234$) with Sta sows being intermediate. At timepoints 2 and 3 (approximately D63 and D91 of gestation, respectively), Dyn sows had more lesions than Sta with Con sows intermediate. Lastly, at timepoint 4 (the day sows were moved to farrowing), Dyn sows had more lesions than Con sows with Sta sows being intermediate (Figure 3.4). The main observation was that lesion scores later in gestation were greater in Dyn, with the overall result (main effect) that Dyn sows had higher lesions than both Con and Sta ($p<0.001$). The skin lesion results for the front, middle and hind regions individually are summarized in Table 3.6. Parity and social status had no effect on lesion scores at any timepoint.

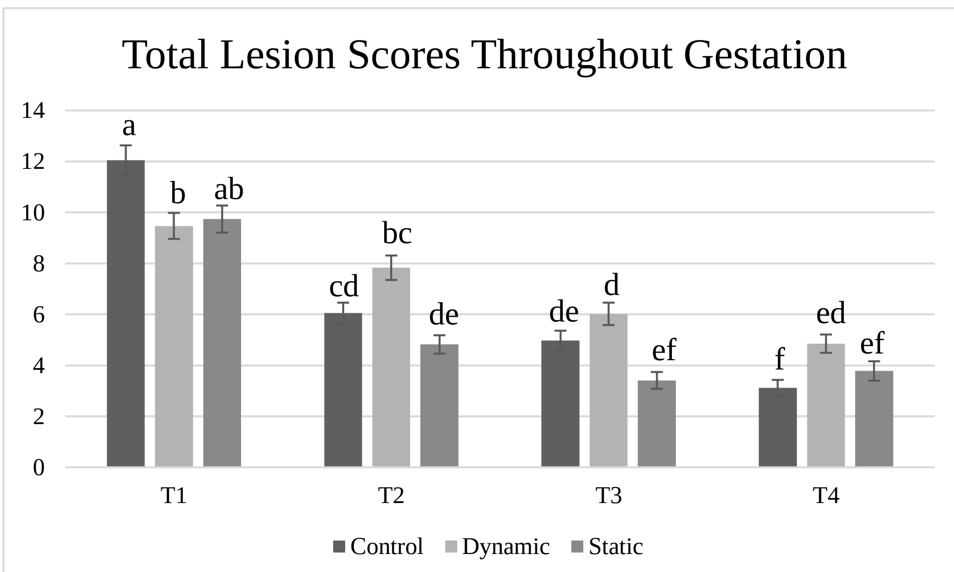


Figure 3.4 Total lesion scores by grouping treatment throughout gestation. Fresh lesions were scored at four different timepoints. T1: 24 hours post-mixing, T2: ~day 63 of gestation, T3: ~day 91 of gestation, T4: on the day of moving to farrowing.

Table 3.5 Total lesion scores by treatment throughout gestation at four different timepoints (T1, T2, T3, T4*).

Timepoint	Treatment**					
	Control		Dynamic		Static	
	n	mean ±SEM	n	mean ±SEM	n	mean ±SEM
T1	74	12.05 ±0.58[a]	78	9.47 ±0.51[b]	74	9.74 ±0.53[ab]
T2	71	6.05 ±0.41[ab]	68	7.83 ±0.48[b]	71	4.82 ±0.36[a]
T3	67	4.97 ±0.39[ab]	66	6.02 ±0.44[b]	67	3.41 ±0.33[a]
T4	55	3.12 ±0.31[a]	65	4.85 ±0.36[b]	44	3.78 ±0.38[ab]

*T1: 24 hours post-mixing, T2: ~day 63 of gestation, T3: ~day 91 of gestation, T4: on the day of moving to farrowing.

**Different superscripts within a row indicate a significant difference (p<0.05) of LS means based on Tukey-Kramer adjustment for multiple comparisons.

Table 3.6 Front, mid and hind lesion scores by treatment* throughout gestation at four different timepoints (T1, T2, T3, T4**).

Region	Timepoint	Treatment					
		Control		Dynamic		Static	
		n	Mean ±SEM	n	Mean ±SEM	n	Mean ±SEM
Front	T1	74	4.74 ±0.21[a]	78	3.93 ±0.19[a]	74	4.12 ±0.20[a]
	T2	71	1.94 ±0.17[a]	68	2.54 ±0.20[a]	71	1.75 ±0.16[a]
	T3	67	1.77 ±0.15[ab]	66	2.19 ±0.17[b]	67	1.29 ±0.13[a]
	T4	55	1.11 ±0.13[a]	65	1.76 ±0.16[a]	44	1.31 ±0.16[a]
Mid	T1	74	3.97 ±0.26[a]	78	2.90 ±0.21[a]	74	2.83 ±0.23[a]
	T2	71	2.05 ±0.19[a]	68	2.39 ±0.20[a]	71	1.70 ±0.17[a]
	T3	67	1.78 ±0.19[a]	66	1.91 ±0.19[a]	67	0.88 ±0.13[b]
	T4	55	1.09 ±0.15[a]	65	1.57 ±0.16[a]	44	1.08 ±0.16[a]
Hind	T1	74	2.54 ±0.21[a]	78	1.80 ±0.18[a]	74	1.70 ±0.18[a]
	T2	71	1.70 ±0.16[a]	68	1.70 ±0.16[a]	71	0.94 ±0.12[b]
	T3	67	1.20 ±0.14[a]	66	1.42 ±0.15[a]	67	0.86 ±0.12[a]
	T4	55	0.69 ±0.11[a]	65	1.00 ±0.12[a]	44	0.93 ±0.14[a]

*Control: 25 sows mixed at ~35 days after breeding into static groups; Dynamic: 25 sows mixed early after breeding into a dynamic group; Static: 25 sows mixed early after breeding into a static group.

**T1: 24 hours post-mixing; T2: ~day 63 of gestation; T3: ~day 91 of gestation; T4: on the day of moving to farrowing.

***Different superscripts within a row indicate a significant difference (p<0.05) of LS means based on Tukey-Kramer adjustment for multiple comparisons.

3.4.4 Correlations

Spearman correlations between lesion scores (recorded in three body regions at four time points during gestation) and sow litter performance traits are presented in Table 3.7. At the first timepoint (T1: 24 hours after mixing), there was a trend for a negative correlation between front and total lesions and live born piglets (p=0.076 and p=0.074, respectively). For the second timepoint (T2: ~mid gestation), there was a trend for a negative correlation between hind lesions and liveborn (p=0.074) and a trend for a positive correlation between hind lesions and still born piglets (p=0.087). At the third timepoint (T3: ~D91 of gestation), there were significant negative correlations between the number of stillborn piglets and the hind region lesions (p=0.034). Lastly, for the fourth timepoint (T4: move to farrowing), there were significant negative correlations between the number of still born piglets and front, hind and total lesions (p=0.018, p=0.030, p=0.028, respectively). In addition, there was a significant negative correlation between litter weight and hind lesions at the end of gestation (r=-0.16, p=0.04).

Table 3.7 Spearman correlations (r and (P values)) between lesion scores evaluated at four different timepoints* throughout gestation and litter characteristics. Significant correlations (p<0.05) are indicated in bold.

	Live	Still	Mummified	Total Born
T1: Front	-0.139 (0.076)	0.020 (0.805)	-0.123 (0.119)	-0.098 (0.213)
T1: Mid	-0.073 (0.357)	-0.005 (0.954)	-0.050 (0.529)	-0.026 (0.743)
T1: Hind	-0.096 (0.225)	0.041 (0.604)	0.107 (0.175)	0.016 (0.841)
T1: Total	-0.140 (0.074)	0.019 (0.805)	0.005 (0.946)	-0.051 (0.520)
T2: Front	-0.076 (0.338)	-0.061 (0.438)	0.018 (0.824)	-0.059 (0.458)
T2: Mid	-0.025 (0.753)	-0.096 (0.224)	-0.003 (0.971)	-0.023 (0.774)
T2: Hind	-0.140 (0.074)	0.134 (0.087)	-0.018 (0.817)	-0.044 (0.580)
T2: Total	-0.096 (0.221)	-0.046 (0.559)	0.016 (0.843)	-0.058 (0.464)
T3: Front	0.006 (0.936)	-0.048 (0.541)	0.001 (0.988)	0.012 (0.890)
T3: Mid	-0.020 (0.799)	0.031 (0.698)	-0.059 (0.457)	-0.009 (0.905)
T3: Hind	-0.047 (0.548)	**-0.166 (0.034)**	-0.011 (0.887)	-0.093 (0.238)
T3: Total	-0.013 (0.868)	-0.062 (0.434)	-0.010 (0.895)	-0.021 (0.788)
T4: Front	0.045 (0.574)	**-0.186 (0.018)**	0.059 (0.454)	0.010 (0.896)
T4: Mid	0.033 (0.675)	-0.092 (0.246)	0.020 (0.799)	0.039 (0.621)
T4: Hind	-0.005 (0.954)	**-0.171 (0.030)**	-0.047 (0.550)	-0.074 (0.346)
T4: Total	0.037 (0.644)	**-0.173 (0.028)**	0.037 (0.639)	0.006 (0.940)

* T1: 24 hours post-mixing; T2: ~day 63 of gestation; T3: ~day 91 of gestation; T4: on the day of moving to farrowing.

3.4.5 Lameness

Results for the percentage of sows observed to be lame (recorded at any evaluation point in the trial) are presented in Table 3.8. The results show that numerically, Dyn sows had a higher incidence of lameness throughout gestation than did Con or Sta sows (chi sq p=0.046). Dominant sows in the Con and Sta grouping had significantly lower lameness than subordinate sows in the same grouping types (chi sq p=0.013 for Con and p=0.004 for Sta) (Table 3.9). Sows across all social rankings in the Dynamic grouping had high incidences of lameness. Parity had no effect on lameness incidence (Table 3.10).

Table 3.8 Percentage of sows observed to be lame at any evaluation point in the trial (n=226).

	Control (%)	Dynamic (%)	Static (%)	Chi-sq p-value
		Lameness		
Lame	24.32	38.46	21.62	0.046
Not Lame	75.68	61.54	78.38	

*Lameness was evaluated every time the skin lesions were scored. Lameness was reported if a sow was observed to be lame (score ≥1) at any evaluation timepoint.

Table 3.9 Percent (%) of sows observed with lameness and farrowing rate by grouping treatment* and social status**.

Item	Control			Chi-sq p-value	Dynamic			Chi-sq p-value	Static			Chi-sq p-value
	Sub	Int	Dom		Sub	Int	Dom		Sub	Int	Dom	
n	33	32	9		39	21	13		29	34	9	
Lameness	45.45	21.88	0.00	0.013	43.59	38.10	23.08	0.420	41.38	11.76	0.00	0.004
Farrowing rate	81.82	81.25	77.78	0.963	87.18	100.00	100.00	0.096	48.28	61.76	88.89	0.090

*Grouping treatment: Control- 25 sows mixed at ~35 days after breeding into static groups, Dynamic- 25 sows mixed early after breeding into a dynamic group, Static- 25 sows mixed early after breeding into a static group.

**Social status: determined for sows in each group as Dom- dominant, Int- intermediate, Sub- subordinate based on feed access in two feed competition tests.

Table 3.10 Percent (%) of sows observed with lameness and farrowing rate by grouping treatment* and parity**.

Item	Control			Chi-sq	Dynamic			Chi-sq	Static			Chi-sq
	Young	Medium	Old		Young	Medium	Old		Young	Medium	Old	
n	34	20	20	p-value	32	28	18	p-value	31	18	25	p-value
Lameness	35.29	25.00	25.00	0.627	40.63	35.71	33.33	0.860	29.03	5.56	28.00	0.130
Farrowing rate	82.35	90.00	70.00	0.263	84.38	96.43	83.33	0.256	58.06	66.67	60.00	0.834

*Grouping treatment: Control- 25 sows mixed at ~35 days after breeding into static groups, Dynamic- 25 sows mixed early after breeding into a dynamic group, Static- 25 sows mixed early after breeding into a static group.

** Parity: Sow parities were grouped as ‘young’ (P0, P1), ‘medium’ (P2, P3) and ‘old’ (P4 and greater).

3.4.6 Hair Cortisol

There were no effects of treatment or social status on hair cortisol at either timepoint. Back transformed LS means ±SEM for timepoint 1 by treatment were Con: 18.43 ±0.15; Dyn: 17.51 ±0.11; Sta: 15.78 ±0.15 (p=0.75). Back transformed LS means ±SEM for timepoint 2 by treatment were: Con: 19.22 ±0.16; Dyn: 18.73 ±0.12; Sta: 18.40 ±0.16 (p=0.98). Parity group had a significant effect at both timepoints. Cortisol concentrations (in pg/mg) by parity group a (in weeks 7 and 12 of gestation) are presented in Table 3.11. The results indicate that at both timepoints, younger sows had significantly higher cortisol concentrations than mid parity sows with old sows being intermediate. Numerically, cortisol levels at the second timepoint were higher than those at the first timepoint.

Table 3.11 Hair cortisol (pg/mg) sampled at 7 and 12 weeks of gestation by parity grouping. The values presented for mean and SEM were back-transformed.

Item	Parity Group* (LS mean ±SEM)			p-values		
	Young	Medium	Old			
N	36	39	36	TRT	Parity	SS
7 weeks	20.82 ±0.11[a]	14.76 ±0.11[b]	16.54 ±0.11[ab]	0.75	**0.04**	0.40
N	37	41	36			
12 weeks	22.88 ±0.11[a]	15.13 ±0.11[b]	19.10 ±0.11[ab]	0.98	**<0.01**	0.23

* Sow parities were grouped as 'young' (P0, P1), 'medium' (P2, P3) and 'old' (P4 and greater).

[a,b] Results with different superscripts within a row indicate statistical significance ($p<0.05$) by post-hoc Tukey-Kramer test.

3.5 Discussion

3.5.1 Comparing Grouping Dynamics

In the current study, Sta sows were the most aggressive within the first 30 minutes of mixing, having a higher frequency of reciprocal fights. In contrast, the Con sows had more lesions in the mid and hind regions and total overall suggesting that Con sows were more aggressive within the first 24 hours of mixing. According to Turner et al. (2006), reciprocal fighting was found to lead to skin lesions on the front of the body while receipt of bullying led to skin lesions on the hind of the body. Since there was no difference in lesions at the front of the body between treatments in this study, the number of reciprocal fights over 24 hrs was likely similar across groups. Strawford et al. (2008) performed four hours of live observations at mixing and found a tendency for sows in static groups (34 to 41 sows) to spend more time fighting than sows in dynamic groups (approx. 105 sows) ($p=0.09$). These results suggest that static grouping results in an increased intensity of fighting at mixing but which may decrease over the following couple hours.

In terms of ongoing aggression throughout gestation, the current study found that sows in the Dyn housing treatment had higher lesion scores from mid-gestation onwards. Similar findings were described by Anil et al. (2006), who found higher total injury scores at two weeks post-mixing for sows housed in dynamic groups, mixed every two weeks, compared to static groups. Based on this result, Anil et al. (2006) concluded that welfare of sows in dynamic groups was compromised. The current study also found that Dyn sows had a higher incidence of lameness throughout gestation than Con and Sta sows, which supports the idea that higher lesion scores in Dyn sows could be an indicator of higher aggression, and which may led to increased lameness. Li and Gonyou (2013) found that sows housed in static groups of 35-40 sows had fewer incidences of lameness throughout gestation than sows in dynamic groups of 105-120 sows, and thus confirms the results of this study. Similarly, a study comparing static and dynamic grouping on 10 commercial farms, varying in group size, in Belgium found that sows housed in dynamic groups had a higher prevalence of lameness at the end of gestation than those housed in static groups (Bos et al., 2016). The increased lameness seen in the dynamic groups of this study as well as others (Li and Gonyou, 2013; Bos et al., 2016), may be a result of lower group stability due to multiple mixing events. In the current study, however; the increased incidence of lameness and skin lesions throughout gestation in dynamic groups did not impact farrowing rate of sows which remained decent.

This study found that sows with more hind lesions late in gestation had fewer still born piglets. Another study that analyzed the correlations between skin lesions and litter characteristics found that sows with more lesions three weeks post-mixing had more mummified piglets (Lagoda et al., 2021). These results indicate that there may be an effect of lesions on litter quality; however, the effects are not significant enough to make a large difference in sow herds.

Hair cortisol concentrations in this study did not differ between grouping treatments, however; it was found that younger sows had the highest levels of cortisol concentrations while mid parity sows had the lowest. Similarly, Strawford et al. (2008), although using salivary cortisol, also found a significant effect of parity where young sows (parity 1) had the highest and intermediate sows (parity 2-3) had the lowest concentration. In contrast, a study comparing two different farrowing systems found no effect of parity on hair cortisol concentrations (Wiechers et al., 2021). Lagoda et al. (2006) looked at associations between hair cortisol and skin lesions and found no significant associations and thus concluded that cortisol extracted from hair was not a useful indicator for chronic stress in sows. Numerically, cortisol concentrations for sows at the second timepoint were higher than at the first, suggesting that cortisol concentrations increase over gestation. Similarly, Hay et al. (2000) found that average plasma cortisol levels increased with stage of gestation.

3.5.2 Comparing Early and Late Mixing

In this study, skin lesions were used as a proxy indicator of aggression between sows. The results from the present study show that sows mixed post-implantation (Con treatment) had higher total skin lesions at mixing than sows mixed pre-implantation (Sta and Dyn treatments). These results suggest that, using skin lesions as an indicator, there is a lower level of aggression when sows are mixed early in gestation. Similarly, the results of Galli et al. (2022), found that sows mixed into static groups later in gestation (D28) had more old scratches in the anterior region at three days post-mixing than sows mixed into static groups early (D4) in gestation. These results contradict those of Strawford et al. (2008) who found that sows mixed post-implantation were less aggressive than sows mixed pre-implantation as measured by the number of aggressive encounters observed at the entrance of the ESF. However, the same study found no significant differences between early and late mixing for injury scores (Strawford et al., 2008). When comparing early (1-7 days post-insemination) and late mixing (35 days post insemination) in static groups of 85 sows, Stevens et al. (2015) also found no differences in total lesion scores, however; they did find that sows mixed at day 0 after insemination had more and longer bouts of aggression than sows mixed at day 35 on the first day of mixing similar to the observations in the current study for early mixed static sows. In the current study, hair cortisol concentrations did not differ between Con sows (mixed late) and Sta and Dyn sows (mixed early). Galli et al. (2021), using salivary cortisol, also found no treatment differences when comparing sows mixed at day 4 to sows mixed at day 28 post-insemination. In contrast, Stevens et al. (2015) found that sows mixed 35 days post-insemination had lower salivary cortisol concentrations at mixing compared to sows mixed within a week post-insemination. Further, salivary cortisol concentrations were lower at 7 days post-mixing and no difference was found between treatments indicating similar levels of stress at mixing (Stevens et al., 2015).

3.5.4 Study Weaknesses

Results from this study only looked at frequency of reciprocal and one-sided aggression for the first half hour after mixing. To fully understand the effects of aggression at the time of mixing, a longer time period after mixing should be observed. Video footage up to five hours post-mixing was recorded in this study but has not been transcribed. The analysis for lameness included simply the presence or absence of lameness. It would be beneficial to know the time period in gestation when lameness was most prevalent.

As this study was performed in a small herd of 320 sows, there were limited opportunities to form treatment groups. As a result, the study ran over a period of 14 months which may have influenced the behaviour and productivity of sows on trial. Another unavoidable consequence of the length of this study includes the possibility for seasonal effects. Although treatments were distributed equally across the year as evenly as possible, seasonal changes might have had an effect on the reproductive performance with the possibility for reduced performance for sows enrolled into the study during the change from summer to fall as the photoperiod shortens.

Another potential weakness of this study was that unlike the Con sows, sows in Sta and Dyn treatments were not confirmed pregnant before being mixed into the group. Thus, sows that were found to be NIP, may have never conceived to begin with. In addition, to form static groups, sows from two consecutive weaning weeks were combined which increased the days pregnant at mixing and thus the stress of mixing occurred closer to the critical period of embryo implantation.

3.6 Conclusions

Static sows had higher frequency of reciprocal aggression initially at mixing while Control sows had higher lesions 24 hours post-mixing. Throughout gestation, Dynamic sows had more lesions and higher incidence of lameness which did not seem to affect farrowing rate or litter quality but suggest that the welfare of Dynamic sows may be compromised. Thus, dynamic mixing may serve as a viable alternative to group housing provided that management strategies are refined to mitigate the effects of ongoing aggression.

4.0 OVERALL DISCUSSION

4.1 Introduction

The Canadian swine industry is currently transitioning housing for gestating sows from individual stalls to group housing (NFACC, 2014). When designing a group housing system, management decisions regarding group dynamics and time of mixing must be made. Producers must choose between implementing static groups (one-mixing event) or dynamic groups (multiple mixing events) and whether to mix the sows early in gestation (pre-implantation) or late in gestation (post-implantation). One main concern with any type of group housing is the aggression performed when mixing sows into a group. As well, and depending on management, varying levels of ongoing aggression may be experienced throughout gestation. In both cases, this aggression is stressful to the sow and has the possibility to impact her productivity. It is therefore important to understand how different housing systems impact both the productivity and wellbeing of the sow.

4.2 Objectives

The main objective of this project was to determine the effects of dynamic mixing practices on sow productivity and welfare compared to static grouping. The purpose of this objective was to determine if dynamic grouping provides a sound and viable housing option for pork producers. Specific objectives were to compare the behaviour of sows in static and dynamic groups, assessing the impact of treatments on sow aggression and injury, to compare the effects of early and late mixing on measures of sow reproduction and lastly, to study the differences between dominant and subordinate sows in static and dynamic groups.

4.3 Discussion

It was hypothesized that dynamic mixing would result in greater social stress as every mixing event would provoke aggression. With regards to aggression at mixing, the current study found that Static sows participated in significantly more reciprocal aggression in the first half hour of mixing (percent of observations where fighting was observed: Control: 11.7%; Static: 36.7%; Dynamic: 10.4%, Chi sq $p<0.001$). This period of intense aggression at mixing could explain why Static sows had a reduced farrowing rate (Control: 81.1%; Dynamic: 88.5%; Static: 62.2%, Chi sq $p<0.001$). Similarly, Strawford et al. (2008) found a tendency for sows in static groups (34 to 41 sows) to spend more time fighting after mixing than sows in dynamic groups (approx. 105 sows) ($p=0.09$). As such, sows in the dynamic group experienced less aggression, and thus presumably less acute stress, than sows in the static group and were similar to late-mixed control sows.

However, throughout gestation, sows across social status in the dynamic groups had higher incidences of lameness (see Table 3.9) and also presented higher total lesion scores than static sows in mid-gestation. These results indicate that the sows housed in dynamic groups were under greater social stress later in gestation. However, the injuries sustained by dynamic grouped sows were not severe enough to impact farrowing rate. Lagoda et al. (2021) suggested that aggression causing chronic stress negatively impacts reproductive performance. Thus, in a group of mixed parity sows, special attention may be needed for smaller, younger sows who may be more likely to rank lower in the dominance hierarchy (Horback et al., 2021). Other studies comparing static and dynamic grouping found similar results where dynamic sows had more injuries (Anil et al., 2006; Li and Gonyou, 2013; Bos et al., 2016), thus affecting their freedom from pain and distress and decreasing their welfare. In contrast, Strawford et al. (2008), did not find any difference between housing management systems in terms of injuries and suggested that a larger group size, provision of sufficient space and group addition intervals no less than five weeks apart may alleviate the negative effects of dynamic grouping. When focusing on the static treatment, dominant sows performed very well with no lameness and a high farrowing rate; while, subordinate sows showed higher prevalence of lameness and very low farrowing rates indicating that social pressure was endured primarily by sows of lower social ranking. Control grouped sows show results indicative of a stable group with subordinate sows suffering more from lameness but limited impact on farrowing rate. In addition, it was found that as the number of skin lesions in late gestation, particularly in the hind region, increased, the number of stillborn piglets decreased. Lagoda et al. (2021), looking at associations between skin lesions (measured 24h and 3 weeks post-mixing) and reproductive performance in static groups of 24 animals per pen, found that sows with the highest total lesions 3 weeks post-mixing had more mummified piglets. In another study, sows that had received more lesions at the end of gestation were the same sows to have lost all fights they were involved in or avoided fights (Brajon et al., 2021). These results indicate that the aggression received even after the initial mixing event may have an impact on the sows' welfare and litter characteristics.

It was also hypothesized that sows mixed early in gestation would have negative effects on reproductive performance. Sows mixed post-implantation (Control) had higher change in total lesion scores particularly in the hind region 24 hours after mixing than did Static or Dynamic sows. These results are contrary to the behaviour observed shortly after mixing, and suggest that overall, sows mixed post-implantation were more aggressive at mixing than sows mixed pre-implantation. In contrast, other research has found that mixing sows post-implantation resulted in a lower frequency of aggression at mixing than sows mixed pre-implantation (Strawford et al., 2008; Stevens et al., 2015). Grouping treatment had no effect on the litter characteristics and although sows in the static group had a reduced farrowing rate, sows in the dynamic group outperformed those of the control treatment which suggests that sows can be mixed early after insemination without negative repercussion on reproductive performance. Although previous research suggests that mixing sows early reduced farrowing rate (Knox et la., 2014; Cunha et al., 2018), a more recent study found that mixing sows 4 days post-insemination into static groups of 21 sows had no negative impact on farrowing rate or litter size compared to mixing sows at 28 days post-insemination, supporting the option of mixing sows early without impacting production (Galli et al., 2022).

When studying the effects of group housing on sows, it is important to understand the body characteristics and behaviours among different parities and social rankings within the group. This study found that as parity increased, body weight gain during gestation decreased which is understandable because gilts and first parity sows have not yet reached their full body weight and are thus still growing as well as producing a litter. Further, gilts and first parity sows had higher body condition and thicker backfat than did older sows. These results are explained by farm management practices, such as stall feeding of gilts in the breeding room and the fact that during gestation gilts and sows received the same daily feed amount in free access stalls, while mature sows had higher feed requirement. Sow parity also played a significant role in the hair cortisol concentrations with young sows having higher cortisol levels than mid parity sows and old sows being intermediate. These findings suggest that young sows experienced greater stress through gestation: more acute stress at mixing and more chronic stress throughout gestation.

It was hypothesized that sows of lower social ranking would perform more poorly especially in dynamic groups. It has been reported that subordinate sows had lower body weights (O’Connell et al., 2003), and tendencies have been reported for younger sows to have more lesions than intermediate and older sows (Stevens et al., 2015; Strawford et al., 2008). Strawford et al. (2008) also reported that older sows entered the feeder earlier in the feeding cycle than did the younger sows which also supports that older sows were more dominant as they had priority access to feed as a limited resource. In addition, Horback et al. (2021), found that sows who laid on the slatted floor in the pen, presumably a less favored area, tended to be sows who were younger and smaller, had more lesions and entered the feeding system later in the day. These findings may lead to the conclusion that young sows are lower in the social hierarchy than old sows. However, the results from this study indicate that social status and parity are not the same and have different effects on sow performance. Based on the results from this trial, social status seems to be a better predictor of sow performance in terms of lameness and farrowing rate. For dynamic grouping specifically, sows across parity and social status appeared to suffer more from lesions and lameness throughout gestation but with no effect on farrowing rate. In this study, feeding sows in free-access stalls eliminated competition for feed, however; if there was greater reason for stress (i.e. competition for feed), social status would be expected to have a greater impact on sow performance.

4.4 Conclusions

Control sows received more lesions at mixing, particularly in the hind region, suggesting that when mixed later in gestation sows were more frequently injured while avoiding their aggressor. Static sows engaged in more aggression immediately after mixing which may indicate greater intensity and be related to their reduced farrowing rate. Aggression within the first 24 hours post-mixing in Dynamic groups appeared to be moderated due to the smaller number of unfamiliar sows introduced at each mixing event, however; sows in dynamic groups experienced greater stress throughout gestation as indicated by skin lesions and lameness but with no impact on farrowing rate. In conclusion, dynamic mixing may serve as a viable housing alternative for pork producers provided that the management strategies, such as group size and mixing intervals, are refined to mitigate the effects of ongoing aggression.

4.5 Recommendations and Future Research

Although the gestation pen design at the research farm allowed different housing conditions to be implemented under the same environmental and management conditions, it is important to note that this research simulated group housing settings. Although the sows were locked out of feeding stalls for over 22 hours per day, they were fed in individual stalls each morning. This may have reduced social conflict which would be present in an ESF system where multiple sows share a feeding station and must que to enter the feeder. In addition, sows were let into stalls on the weekends so this may have confounded the study. Due to availability of animals, mixing events for the dynamic treatment sometimes occurred earlier than the four-week period as the initial protocol stated. The study also ran over a year and as such there may have been seasonal effects on the treatments even though treatments were spread out as best as possible.

Pregnancy checks were not conducted on as timely a basis during this study as they should have been. As such, it is difficult to say when during gestation the sows on trial lost pregnancies and in the case of static and dynamic treatments, sows may not have even conceived. As in many other studies, farrowing rate was used as a productivity indicator to evaluate the reproductive performance of sows. However, it is important to note that in this study, the farrowing rate was calculated based on the number of sows bred and included sows that needed to be removed from the trial due to lameness but which had still farrowed and should thus be kept in mind when comparing the rates of this study to others.

Further work needs to be completed to refine management practices for sows in groups. As commercial farming practices frequently feature dynamic mixing with large group sizes, future studies should explore dynamic mixing in larger group sizes, looking at the timing of mixing events and ratio of sows added. Specifically, methods to reduce aggression at mixing as well as ongoing aggression are needed to mitigate the effects of fighting, with particular attention to younger and/or subordinate sows.

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APPENDIX A

Protocol for Mixing Sows

Purpose: Describe procedure for mixing sows into groups, 0 to 11 days after breeding or after pregnancy check at 4-5 weeks gestation.

Equipment: Sow ID list, Livestock crayons (blue, green), 2 paddles, 2 boards, 2 cameras (charged, with clean SD cards, charger, extension cords).

Staff: 3 or 4 people

Mixing will occur on Friday mornings. Staff will be in the barn by ~7:30am. Mixing will take place between 9 and 10am. Lesion scoring will be done before (i.e. on Thursday or Friday morning prior to mixing). All gilts in the group should be weighed in advance. Pen behaviour will be recorded from the start of mixing for a total of 5 hours to record aggression and enrichment interactions.

1. Scrape and otherwise prepare the receiving pen.
2. Add or check enrichment devices, add chains and carabiners to lock stalls.
3. Leave most stalls open to give sows somewhere to go when filling the pen.
4. Clean and label any stalls needed to house ‘extra’ bred sows that are not in the study group.
5. Move out any sows that are in the pen and not on trial. Make sure Tatjana knows/approves where any sows are moved to.
6. Add a small amount of feed to troughs and scatter on solid floors to ‘entertain’ incoming sows.
7. Install 2 cameras: one for slatted and one for solid area.
8. Mark the study sows that are entering with livestock crayons so they are clearly visible in mixing videos. Indicate sow markings on the Sow ID list.
9. Move ‘extra’ bred sows that are not on trial into the labelled stalls where they will be housed individually.
10. Put all gates in place to control sow movement.
11. Start the video cameras. Demonstrate/record the 1 m distance away from enrichments.
12. Move sows and gilts into the pen. At least 3 people are needed.
    a. One person moves sows out of breeding stalls, a second person holds the gestation room door and tries to keep sows in gestation room, a third person with handling board keeps sows in the pen, while allowing incoming sows to enter (the goalie). Some sows may exit the pen but will be herded back into the pen.
13. Move and lock sows out of stalls.
14. After 5 hours recording has elapsed- remove the video cameras for file recovery.
15. At end of day (2:30-3:00pm) undo chains and carabiners to allow sows into stalls overnight for the weekend.

APPENDIX B

Protocol for Nutritional Enrichment Provision

Purpose: To describe the procedure for preparing an extra source of fibre for sows right after morning feeding to entice sows to come out of their stalls.

Materials: Beet pulp, hay cubes, four pails, a scoop with measurement indicators, water

Procedure: for a pen of 25 sows

1. Using a scoop, measure out one quart of hay cubes and two quarts of water into a pail. Allow to soak overnight.
2. The following morning prior to opening stalls, add two quarts of beet pulp and three quarts of water to the pail with the hay.
3. After letting sows in stalls and dropping feed, distribute the mixture of soaked fibre onto the solid floor area of the gestation pen.
4. Rinse pails with water and measure out hay for the following day.

APPENDIX C

Protocol for Backfat Measurement Procedure

Purpose: Describe procedure for recording back fat.

Background: Backfat range: thin = 11 mm, normal = 18 mm, fat = 24 mm

Equipment: Probe (ImaGo S - Veterinary Portable Ultrasound Monitor), iPad, tape measure, Sharpie marker, electrode gel (can be diluted, 1/3 water: 2/3 gel), Sow list

Staff: 1 or 2 staff

1. Turn on iPad (top right button) and turn on probe
    a. iPad Settings- select probe wireless connection
    b. Open Back fat application
2. Check settings: 2 mm
3. Click on sow info and Enter sow ID and treatment
4. Use probe or iPad to select LIVE mode
5. Sow should be standing. Locate P2 position: first locate last rib and centre of spine marking an X on the sow's back, then make a dot 65 mm from the dorsal mid-line.
6. Put electrode gel on sow at the marked X
7. Put probe head in contact with sow at P2 position (65 mm from the dorsal mid-line at the level of the last rib) ensuring the orientation of probe is parallel to the spine.
8. When suitable image is on the screen, press FREEZE button.
9. Select 'Measurement' icon and using the touch screen adjust bottom line to location at base of third fat layer.
    a. There are three backfat layers: first or outer backfat layer, the second or middle backfat layer (thickest), and the third or inner backfat layer. They appear grey on ultrasound, separated by white layers of connective tissue.
10. Press save. Check that Sow image and measurement are saved in iPad folder.
11. Proceed to next sow and repeat steps 2 to 8.
12. Once all sows are done, turn off and clean probe and iPad using paper towels. Charge equipment if battery is low. Store equipment in Ethology Lab Dynamic Mixing cupboard.