RESEARCH REPORT

ANIMAL WELFARE

Title: Weaning sows directly into group housing: Effects on aggression, physiology and productivity **– NPB #13-091**

Investigator: Dr. Jennifer Brown

Institution: Prairie Swine Centre Inc., Saskatoon, SK, Canada

Date Submitted: July 15th, 2015

Industry Summary

In the management of group housed sows, keeping sows in stalls from weaning until five weeks after breeding is a common strategy that serves to prevent aggression, control individual feed intake and facilitate management during breeding. However, pressure to reduce stall use continues, and alternative management options should be explored to determine what other viable options are available to producers. This study compared the effects of three mixing strategies on sow performance in fully-slatted group pens, with sows fed daily in free-access stalls. A total of 252 sows were studied over six replicates, in groups of 14 sows/pen (2.2 m^2/sow). The treatments consisted of: i) Early mixing (EM) - sows mixed into groups at weaning; ii) Late mixing (LM)- sows stall-housed at weaning and mixed at five weeks gestation; and iii) Pre-socialization (PS)- sows mixed for two days after weaning, then stall housed for breeding and up to five weeks gestation, after which they were mixed (same groups). The PS treatment provided an intermediate treatment to examine the interaction between mixing at critical time points in combination with housing sows in stalls during the implantation period. The PS treatment also allowed us to study whether aggression at remixing can be reduced if sows have previously established their social order. For consistency, all treatment groups were housed in free-access stall pens in one gestation room. The free-access stalls were used to house sows during feeding, and for heat checks and breeding. Sows were fed each morning in free-access stalls, after which they were locked out of the stalls, ensuring that sows spent up to 22 hours per day in the loafing area. It was of interest to determine whether measures of aggression, sow welfare and sow reproductive performance (wean-to-service interval, conception rate, and farrowing performance) differed among treatments. Estrus behavior was measured on days 3 and 4 after weaning in the EM group only, to determine if keeping sows loose from weaning can help to stimulate group estrus behavior.

Results indicate that the EM treatment had the highest conception rate (98%), followed by the PS treatment (94%) with the LM treatment having the lowest conception rate (87%). This may reflect sub-optimal stimulation of estrus in stall housing (LM). In comparison, the EM and PS groups received mixing stress immediately at weaning, which may have stimulated follicular growth and clearer estrus expression. The EM treatment also showed a significant reduction in the number of stillborn piglets, which may be an effect of improved sow fitness and/or activity levels during early gestation. There were no other differences in production performance among the treatments. There was no difference in the amount of aggressive behavior performed at mixing, not even when comparing the second mixing of the PS treatment to the first mixing of EM and LM. Between the treatments,

there were no significant differences in cortisol levels or sow lameness. Injury scores were lower in PS sows compared to EM and LM sows after the first mixing. When remixed, sows in the PS treatment had significant increase in injuries than following the first mixing. However, injury scores on all sows were very low. Overall, this suggests that sow welfare was not significantly affected by any of the mixing treatments.

It can be concluded that under good conditions of management, where sows are housed in static groups and individually fed, mixing sows at weaning does not negatively impact sow performance or welfare. Furthermore, there may be production advantages to be gained from mixing sows into groups at weaning, as evidenced by improved conception rates and reduced stillborns, and these effects should be explored further. For the PS treatment, although production levels were acceptable, the mixing of sows twice did not result in reduced aggression and did not provide any obvious advantage.

Researcher contact information: Dr. Jennifer Brown, Prairie Swine Centre, PO Box 21057, 2105 8th Street E., Saskatoon, SK, Canada, S7H 5N9, Tel: 306 667-7442, Email: jennifer.brown@usask.ca

Keywords

Sows, aggression, mixing, stress, estrus behavior, group housing

Scientific abstract

Social stress from mixing has the potential to negatively affect sow reproduction and welfare. Housing sows in stalls from weaning until five weeks after breeding is a common strategy used to prevent aggression and ensure control over individual feed intake during breeding, conception and implantation. However, pressure to reduce stall use will likely continue, and alternative management options should be explored. This study compared the effects of three mixing strategies on sow performance in fully-slatted pens. A total of 252 sows were studied over six replicates, in groups of 14 sows/pen (2.2 m2/sow). Treatments consisted of: i) Early mixing (EM)- sows mixed into groups at weaning; ii) Late mixing (LM)- sows stall-housed at weaning and mixed at five weeks gestation; and iii) Pre-socialisation (PS)- sows mixed for two days after weaning, then stall housed for breeding up to five weeks gestation, after which they were mixed (same groups). Sows were fed once daily in free-access stalls, after which they were locked out of the stalls, ensuring that sows spent up to 22 hours per day in the loafing area. Breeding and farrowing performance were recorded, as well as sow aggression for two days after mixing, sow lameness, injury score and saliva cortisol before and after mixing. Conception rates differed among treatments, with EM sows having the highest conception rate (98%), followed by PS sows (94%), and LM sows had the lowest conception rate (86%). There were significantly fewer stillborn piglets in the EM treatment, but no other production differences were found. There were no significant differences among treatments in the amount of aggression displayed after mixing, changes in lameness before and after mixing, and over the course of gestation. After the first mixing, the PS treatment had significantly lower skin injuries compared to the EM and LM treatments. There were no significant differences in cortisol levels before and after mixing among the treatments. The lower conception rate in the LM sows may reflect sub-optimal stimulation of oestrus during stall housing. In comparison, the EM and PS groups received mixing stress immediately after weaning, which may have stimulated follicular growth and clearer oestrus expression. A tendency for fewer stillborn piglets in EM sows may result from improved fitness and/or activity levels during early gestation. The lack of difference in aggression, cortisol or lameness score between the treatments suggests that sow welfare was not compromised by any of the

treatments. These results indicate that, under good management conditions, mixing sows at weaning does not negatively impact sow performance or welfare.

Introduction

The use of stalls for housing gestating sows has been increasingly criticized for restricting sow behavior and failing to provide adequate welfare for sows. As a result, producers in a growing number of countries are under pressure to convert to group sow housing.

Mixing sows to form groups for gestation inevitably results in aggression and stress as a new social hierarchy is established. Although relatively short-lived, aggression at mixing can have a negative impact on the well-being and performance of sows, and should not be overlooked (Arey and Edwards, 1998). Aggression increases the risk of injury sustained through fighting (Hodgkiss et al., 1998; Li et al., 2011) and increases stress levels in sows, as measured through cortisol (Hemsworth et al., 2006; Li at al., 2011) and heart rate responses (Marchant et al. 1995). Management of sows in groups with restricted feeding has the potential to escalate aggression, as sows compete for access to food over the duration of gestation. Thus, the development of group sow management practices that reduce aggression is of continued importance.

The precisely timed behavioral, physiological and endocrine changes of the estrus cycle are of significant importance to the success of reproduction in female pigs (Turner et al., 2005). Social stress has been linked to a number of detrimental effects on sow reproductive performance, including delayed estrus, abortion, increased farrowing time and agalactia (Arey, 1999, cited in Barugh and Chidgey, 2011). Concern over disruption to the estrus cycle and embryo implantation, coupled with the desire to manage sows for optimal feeding and re-breeding are the main reasons producers operating group gestation systems choose to keep sows in breeding stalls for the first 28 days of pregnancy. Indeed, supporting the use of breeding stalls, research has shown that when sows are mixed during the implantation period, the mixing stress causes a reduced conception rate (Spoolder et al. 2009).

Compared with sows that were mixed two weeks after mating, sows that were mixed five weeks after mating initiated fewer aggressive interactions, sustained fewer skin lesions after mixing, and had higher farrowing rate (Strawford et al., 2008; Spoolder et al., 2009), suggesting that mixing of sows after the confirmation of pregnancy not only ensures successful implantation, but is beneficial for reducing aggression. However, increasing demands for group housing of sows, may lead to increasing pressure to remove the use of stalls for the first 4-5 weeks of gestation, as is already being seen in the EU, with recent Dutch legislation requiring sows to be housed in groups from four days post insemination (Ministerie van Economische Zaken, 2013). Producing totally ‘stall-free’ pork would require mixing sows at weaning.

The mixing of sows at weaning is a management approach that has not been investigated extensively, and there may be benefits to this practice that are overlooked. Swine producers in the UK have not used gestation stalls since 1999, and farms achieve acceptable production figures (BPEX, 2012), and report satisfaction with this practice. The average performance of all UK breeding herds being 80% conception rate, 2.26 litters/sow/year and 27 pigs born/sow/year, and the top 10% of UK farmers having 86% conception rate, 2.37 litters/sow/year and 33 pigs born/sow/year (BPEX, 2012). Without the need for breeding stalls, utilization of building space can be optimized, allowing more space and/or maintaining herd size during housing conversions. A large scale comparison on commercial farms in Europe indicated that mixing sows at weaning did not affect farrowing rate, but reduced litter size by 0.6 piglets compared with sows that were mixed 4 to 5 weeks after mating (Danske Slafterier, 1995). As mixing at weaning occurs before mating, it may alleviate the detrimental effect of aggression on conception rate (Spoolder et al., 2009). There is also evidence to suggest there are stimulatory effects of stress on the reproductive system of pigs that may enhance the return to estrus in newly weaned sows. Stress from transport has been found to advance the onset of puberty in gilts (Hughes, 1982, cited in Turner et al., 2005). In human women, acute stress has been found to cause a surge in luteinizing hormone in the presence of high levels of plasma estradiol, generating ovulation (Tarin et al., 2010). In cyclic gilts, Turner et al (2005) showed that the process of ovulation is only disturbed in sows that had a chronic (prolonged) elevation of the stress hormone cortisol, and not when levels were elevated acutely (transiently). These studies provide evidence suggesting that if the stress is acute, there may be a positive effect on reproduction from mixing sows at weaning, or at least no negative effects. However, other authors have suggested that disruptive changes to the endocrine system prior to estrus are likely to inhibit reproduction (Moberg, 1985, cited in Turner et al. 2005). This question needs to be investigated further in order to provide producers with the information needed to make decisions on the optimal management of sows in groups, and what options are available and viable. This is the purpose of the current study.

References

Arey, D. S. and Edwards, S.A (1998) Factors influencing aggression between sows after mixing and the consequences for welfare and production. *Livestock Production Science* **56**: 61-70.

Barugh, I. and Chidgey, K (2011) Sustainable dry sow housing and management. Sustainable farming fund project 07/071. Massey University, New Zealand.

BPEX (2012) The Pig Yearbook. Agriculture and Horticulture Development Board, Warwickshire, UK.

Danske Slagterier (1995) Transfer strategy. In: Annual Report, The National Committee for Pig Breeding, Health and Production. Danske Slagterier, Copenhagen, p. 16.

Hemsworth, P. H., Stevens, B., Morrison, R., Karlen, G.M., Strom, A.D. and Gonyou, H.W (2006) Behavior and stress physiology of gestating sows in a combination of stall and group housing. *Proceedings 40^th^ International Society for Applied Ethology*, University of Bristol. p. 111.

Hodgkiss, N. J., Eddison, J.C., Brooks, P.H. and Bugg, P. (1998) Assessment of the injuries sustained by pregnant sows housed in groups using electronic feeders. *Veterinary Record* **143**, 604-607.

Li, Y. Z., Baidoo, S.K., Johnston, L.J. and Anderson, J.E. (2011) Effects of tryptophan supplementation on aggression among group-housed gestating sows. *Journal of Animal Science* **89**, 1899-1907.

Marchant, J.N., Mendl, M.T., Rudd, A.R. and Broom, D.M. 1995. The effect of agonistic interactions on the heart rate of group-housed sows. *Applied Animal Behavior Science* **46**, 49-56.

Ministerie van Economische Zaken (2013) Enforcement actions group housing of pregnant sows Netherlands. A presentation by the Ministry of Economic Affairs. Available online at: http://ec.europa.eu/dgs/health_food-safety/information_sources/docs/ahw/28012013_pres_arnts.pdf Accessed 19th June 2015.

Spoolder, H. A. M., Geudeke, M.J., Van der Peet-Schwering, C.M.C and Soede, N.M (2009) Group housing of sows in early pregnancy: A review of success and risk factors. *Livestock Science* **125**, 1-14.

Strawford, M. L., Li, Y.Z. and Gonyou, H.W. (2008) The effect of management strategies and parity on the behavior and physiology of gestating sows housed in an electronic sow feeding systems. *Canadian Journal of Animal Science* **88**, 559-567.

Tarin, J.J., Hamatani, T. and Cano, A. (2010) Acute stress may induce ovulation in women. *Reproductive Biology and Endocrinology* **8**, (53).

Turner, A.I., Hemsworth, P.H. and Tilbrook, A.J. (2005) Susceptibility of reproduction in female pigs to impairment by stress or elevation of cortisol. *Domestic Animal Endocrinology* **29** (2): 398 – 410.

Objectives

Working with static groups of sows, the objectives of this project were to:

1) Determine effects of mixing sows at weaning vs. mixing at five weeks after mating on reproductive performance, aggression and associated stress.

2) Evaluate whether pre-mixing sows for two days after weaning, followed by breeding in stalls, can improve the reproductive performance of sows that are grouped after implantation.

In conducting research to meet these objectives, further deliverables include thorough evaluations to determine:

1) Whether placing sows directly into group housing after weaning is a viable option for pig producers, i.e. one that does not cause undue stress to sows and maintains reproductive efficiency.

2) How levels of aggression differ: a) when mixing is performed directly after weaning; b) when mixing is performed at five weeks post breeding; and c) when mixing is performed at weaning and again at five weeks post breeding.

3) What effect these different mixing times have on stress physiology and reproductive performance, and whether

mixing at weaning can enhance the reproductive performance of sows.

Materials and Methods

7.1 Animals and Housing

The study took place at the Prairie Swine Centre's research farm, a 330 sow farrow-to-finish unit located in Saskatchewan, Canada. A total of 252 Large White X Landrace sows (PIC, Hendersonville, TN), were studied across three treatments, tested in six replicates. All gestating sows were group-housed in free-access stall pens, with six pens in one room. Each pen had 32 gated free-access stalls (0.61 x 2.13 m) and a fully slatted communal loafing area (3.05 x 10.72 m). Each pen could accommodate 32 sows, providing 2.32m^2 per sow (stall and communal loafing area). This group system allows individual feeding of sows, yet provides sows with the option of remaining in the stall or exiting to loaf in the communal exercise area. All sows were fed a commercial dry sow ration appropriate to their needs following standard commercial practice. Water was provided by a single nipple drinker per stall for access during feeding, and also a water nipple added at one side of the communal exercise area. Sows were bred on a weekly basis, with 14 sows bred per week, resulting in one gestation pen being filled every two weeks. To remove effects of room, all sows were housed in the gestation room from weaning, with the free-access stalls used to house sows for breeding stalls. Piglets were weaned at 28 days of age.

7.2 Experimental treatments

Three treatments were compared over six replicates, resulting in a total of 18 pens studied. Treatments were; i) Early Mixing (EM): sows mixed into groups for insemination and gestation directly from weaning (14 sows per pen group), ii) Pre-socilization (PS): sows mixed into groups directly after weaning, held in groups for two days, then housed in stalls for insemination until five weeks post breeding, after which sows were released back into the group, iii) Late Mixing (LM): sows mixed intro groups after being housed in stalls from weaning until five weeks post breeding. The EM and LM treatments evaluate two common management strategies, with the LM acting as a control. The PS treatment provides an intermediate treatment to investigate in further detail the interaction between mixing at critical time points in combination with housing sows in stalls to enable sows to avoid social pressure during the period of implantation. Specifically, the PS treatment will help to examine if mixing at weaning can enhance the return to estrus, if there are production benefits to housing sows individually from insemination to five weeks gestation, and whether aggression at remixing will can be reduced if sows have previously established their social order.

Each experimental pen group contained 14 sows of mixed parity, to match the herd demographics (0-9), with parity balanced across treatments. To accommodate the production flow of the barn, 14 additional sows were housed in the pen to ensure a full pen of 28 sows. However, these additional animals were not under study, and were held in one row of free-access stalls for the duration of gestation to prevent interference with the sows on trial. Managing the sow groups in this manner also ensured that the 14 sows per experimental pen group could have sufficient space in the communal area for mixing and displays of aggression, with a total space allowance in the group area of 2.34 m^2 per sow. For all treatments, heat detection, A.I. and diagnosis of pregnancy took place with sows locked in the free-access stalls.

The treatments were managed as follows:

<u>Early Mixing (EM):</u> At weaning, 14 sows were placed directly into a gestation pen. Daily, sows were fed in the stalls in the morning and were then locked out of stalls for the remainder of the day to ensure socialization of

sows within the communal loafing area. This routine was maintained daily for sows, from weaning until they were moved to farrowing.

Pre-socialization (PS): At weaning, 14 sows were placed directly into a pen, fed in feeding stalls, and then locked out each day following feeding to ensure mixing and social contact in the communal area. At two days post weaning, sows were locked into the stalls for breeding, where they remained until five weeks after breeding. At five weeks gestation, sows were released from the stalls and group-housed in the communal loafing area. Sows were fed in the feeding stalls each morning, and then were locked out in the communal area for the remainder of the day.

Late Mixing (LM): As the control group, sows were managed as is common in commercial practice. Following weaning, sows were placed directly into free-access feeding stalls (acting as gestation stalls), and locked in. Sows remained in the stalls for breeding and until five weeks after. At five weeks gestation, sows were mixed and were group-housed in the communal loafing area. Sows were allowed into the stalls each morning for feeding, and were locked out of stalls for the remainder of the day to ensure socialization of sows within the loafing area. This routine continued until the sows were moved to farrowing.

The purpose of locking sows out of the free-access stalls following feeding was to simulate group housing systems where sows are required to remain within a group, as in ESF, floor feeding, or short stall systems. If allowed continued access to feeding stalls, it can be expected that the majority of sows would remain in stalls most of the time, with minimal treatment differences compared to stall housing. To maintain static groups within each pen, sows that returned to estrus and were not pregnant after mating at the second estrus were recorded, but remained in the pen to maintain stocking density.

7.3 Measurements

7.3.1 Sow production performance

Measures of sow reproductive performance were collected including wean to standing heat interval, conception rate to the first or second service, total pigs born(alive, mummified, stillborn), pigs weaned and weaning weight. Sows culled during the trial and the reasons (reproductive failure, lameness and other) were recorded.

7.3.2 Sow body condition

Individual body weight, back fat depth and body condition score (BCS) was recorded on all sows at weaning, five weeks after mating and before moving to farrowing accommodation. BCS was measured according to Coffey et al. (1999), backfat thickness was measured by an ultrasonic scanner by a trained technician.

7.3.4 Aggression at mixing

Behavior of all pens was recorded by video camera for the designated mixing. A camera was suspended over each pen, and set to record from 09:00 – 16:00 for two days, starting on the day of mixing. Prior to mixing, all sows were individually identified with a pattern of lines spray marked on their backs for clear identification. Footage was transcribed in real time by trained observers who were blind to treatment and the total number and duration of aggressive bouts was recorded. Aggressive interactions were defined as outlined in the ethogram in Table 1. Through the individual identification of sows, the number of times over the two days of footage that each individual participates in an aggressive encounter was recorded.

Table 1. Ethogram of sow behaviors recorded for evaluation of aggression at mixing and sexual behavior

Aggressive Behavior	Description
Fight: Head to head or head to back	Engaging in mutual pushing/ramming of an opponent with the head/shoulders in rapid succession, with or without biting (O'Connell et al. 2003)
Threat	A sow bites or makes a threatening gesture towards another sow and the sow retreats without reciprocating
Retreat	Sow who flees from aggressive encounter
Sexual Behavior	
Sow mounting	Sow attempts to mount another sow. Mounting attempt can be on any part of the sow, e.g. the head or back. If the sow's front feet are seen to leave the ground it is classed as mounting.
Flank nosing	Sow noses the flanks, belly or shoulder of another sow, simulating boar stimulation

7.3.5 Estrus Behavior

Sows in the EM treatment only were observed for estrus behavior on day three after mixing. Mounting and flank nosing behaviors were recorded, following the ethogram for sexual behavior in Table 1.

7.3.6 Injury and lameness

Sows were assessed for skin injury and gait scored for lameness before mixing, at 48 hours after mixing, and on the day of moving to farrowing accommodation. Skin injury was assessed using a scratch score method developed by Hodgekiss et al. (1998), which combines scores of 0 – 3 from 12 surface regions of the body: two ears, snout, two shoulders, two flanks, two hindquarters, top of the back, the tail and the vulva. Lameness was assessed using the Zinpro Feet First® gait scoring system, using a scale from 0-3, with 0 being not lame and 3 being severely lame.

7.3.7 Saliva Cortisol

Saliva samples were collected from four focal sows per pen for measurement of cortisol to assess the degree of stress induced by mixing. Samples were collected at three time points: before mixing, 24 hours post-mixing (during day two of mixing) and 72 hours post mixing. Samples were collected at the same time each day to account for the natural circadian rhythm in cortisol levels. Saliva was collected from individual sows on cotton swabs skewered on a thin metal rod, and held in place by a rubber bung. The saturated cotton was stored at -20°C until analysis. Samples were analyzed at a local laboratory using a solid-phase, competitive chemiluminescent enzyme immunoassay: Immulite (Siemens Healthcare, GmBH, 2015). This assay had previously been validated for use with pig saliva (internal validation study at PSC). The assay is sensitive to5.5 nmol/L, with within-run CVs of 8.8 and 7.8% (sample means 74 and 312 nmol/L).

During one EM replicate (summer 2013), 30% of the animals on trial either were determined not in pig. With such a large number of animals affected, it was decided that factors outside the study were responsible, especially as this replicate occurred in the warm summer months. Therefore data from this one EM replicate were excluded and an additional replicate was run to replace it, ensuring six EM replicates in total.

1.4 Statistical analysis

7.4.1 Calculations: Prior to statistical analysis calculations were performed to prepare the data for analysis. Sow parity was categorized as follows: Gilt – all animals being bred for the first time; Young- sows of parity 1 and 2; Medium- sows of parity 3 and 4; Old- sows of parity 5 and above.

Per treatment, observations of aggressive behavior were collated to determine the total number of aggressive interactions on each of the two observation days. Aggressive interactions were classified as a threat, head-to-head fight or head-to-back fight. To account for variation in the total duration of video footage recorded, the total time spent in aggressive interactions over the two days of observations was calculated as a percentage of the total time observed. The total number of threats, head-to-head and head-to-back interactions per hour were calculated separately for the two days of observations.

For the EM group only, observations of estrus behavior in the group pen on days 3 and 4 post weaning were determined per day, as well as the total number of sexual encounters, the total duration of time spent performing estrus behavior, total number of mounts and flank nosing, percentage of the total observation time sows were performing estrus behavior and the percentage of sows within the pen group involved in estrus behaviors. These figures were analyzed using a paired t-test to determine any significant changes in the amount of estrus behavior performed between days 3 and 4.

The wean-to-service interval was calculated as the number of days from weaning until the sow was first bred. Gilts were excluded from this data. Conception rate was calculated as the total number of animals on trial that did not return after the first breeding. Animals that received PG600 were excluded from this data.

Statistical analysis was conducted in the statistical package SAS 9.3 (SAS Inst. Inc., Cary, NC, USA). All data were checked for normality and then analyzed with the appropriate test accordingly.

7.4.2 Sow performance: The effects of treatment and parity on sow production performance (total born, born alive, stillborn, mummified, wean to service interval) were analysed with Proc Glimmix, with gussian distribution used for normal data, and where appropriate for non-normal data, poisson distribution with the log-link function to transform least square means back to the observed scale for interpretation. Differences between least squares means were identified using the Tukey-Kramer adjustment. Replicate was not included in the statistical analysis as one sow group entered the study every two weeks, so replicate had no actual representative weight. Treatment and parity score were included in the model as fixed effects. Gestation pen was initially included as a random effect, but was removed as it was shown to have no effect. Due to cross fostering practices, it was not possible to accurately determine the number of piglets each sow raised and weaned. The Fishers exact test was used to determine differences in the number of animals that successfully conceived per treatment.

7.4.3 Aggressive behavior: Proc Mixed was used to compare aggressive interactions among treatments for each of the mixing times. This was done in two phases, first comparing the EM, LM and the first mixing of the PS, and second, comparing the EM, LM and second mixing of the PS treatment. The effect of observer and replicate were tested in the model as random effects. However, neither had a significant effect, and thus were removed from the final analysis.

7.4.4 Sow skin injury and lameness: For each of the scratch scores measurements, the average score was calculated per side of the sow and the average from each side added together, producing a total average scratch score. Changes in the skin injury score, cortisol and lameness between the measurements were calculated, producing delta values. Differences in the delta values between treatments was analyzed between treatments using either Proc Mixed or Proc Glimmix as described above. For change in lameness and skin injury score pre and post mixing, the data from the second mixing of the PS was analyzed alongside the data from the EM, LM and PS initial mixing, as a preliminary analysis to compare means. The treatment was coded (PS2) to be distinguished in the data set. Due to a large number of the cortisol samples having results below the limit of detection, a decision was made to include the cortisol results from the second EM replicate, that was previously removed from other analysis. This was done in order to increase the number of results available for analysis and because there had been no cortisol measurement taken for the additional EM replicate that had been run.

Results

8.1 Sow parity, body condition score and culling

There was no difference in the parity score of sows among treatments, (EM: 2.29 ± 0.11; PS: 2.58 ± 0.11; LM: 2.44 ± 0.11; P = 0.172). There was no difference in BCS among treatments, either at weaning as sows entered the trial (EM: 3.0 ± 0.2; PS: 2.8 ± 0.2; LM: 2.8 ± 0.2; P = 0.765), the middle (P = 0.992), or at the end of the trial (EM: 3.3 ± 0.2; PS: 3.4 ± 0.2; LM: 3.2 ± 0.2; P = 0.841), suggesting that treatments were balanced, and that sows maintained good body condition throughout the trial.

Over the course of the trial two sows were culled from the PS treatment, three sows from the EM treatment and eight sows from the LM treatment representing 2%, 4% and 10% of the total sows studied over the course of six replicates per treatment respectively. All PS and LM sows culled due to being found not in pig (NIP), whilst in the EM treatment, one sow aborted, one was found NIP and one sow was non-ambulatory.

8.2 Reproductive performance

Excluding gilts and sows that received PG600 (serum gonadotropin and chorionic gonadotropin for the induction of estrus, Merck Animal Health, Quebec, Canada), there were no differences in the wean-to-service interval between treatments (table 2). Sows that failed to show any signs of standing heat were given PG600 to stimulate the onset of heat. Of animals that received PG600, equal numbers of sows received PG600 among treatments (one sow per treatment).

8.3 Conception rate

Conception rate differed among treatments (Table 2), with the EM treatment having the highest conception rate, at 98%, followed by the PS treatment. Surprisingly, the LM ‘control’ treatment (the standard practice on this farm) had the lowest conception.

Numerically, no gilts in the EM treatment repeated while on trial, whereas in the PS group 8% of gilts repeated, as did 27% of gilts in the LM group.

Table 2. Production characteristics of sows in three mixing treatments: Early Mixing (EM); Pre-Socialization (PS); and Late Mixing (LM).

	Treatments			
Variable	EM	PS	LM	P
Conception rate (%)	97.62	94.05	86.9	0.028
Wean to Service Interval (days)	4.06	4.51	4.31	0.672
Total born	15.16 ± 0.39	15.63 ± 0.40	15.47 ± 0.42	0.700
Born Alive	13.66 ± 0.41	13.27 ± 0.42	13.18 ± 0.45	0.691
Still born	0.95*a* ± 0.12	1.54*b* ± 0.16	1.58*b* ± 0.16	0.003
Mummies	0.47 ± 0.09	0.44 ± 0.09	0.53 ± 0.09	0.766

There was no difference in the total number of pigs born, born alive and mummified among treatments. However, a significantly lower number of stillborn piglets were born to sows in the EM treatment.

8.4 Behavior

8.4.1 Estrus behavior

In EM sows, which were grouped at weaning and could express sexual behaviors, the pen mean of all estrus behaviors, the duration of time engaged in estrus behaviors and the percentage of sows per pen group involved increased numerically from day 3 to day 4 after weaning (Table 3).

Table 3. Estrus behavior observations in EM sows on days 3 and 4 after weaning (mean ±S.D, per group of 14 sows)

Day	3	4
n =	5	6
Number of estrus behaviors	5.6 ± 4.83	14.83 ± 15.00
Total duration of estrus behaviors (s)	315.00 ± 290.23	633.83 ± 604.04
Total mounts	3.60 ± 6.07	7.00 ± 4.69
Total flank nosing	29.40 ± 27.54	73.67 ± 84.63
Percentage of observed time sows spent in estrus behaviors (%)	1.05 ± 0.95	2.31 ± 2.31
Percentage of sows involved per pen (%)	31.43 ± 24.01	47.62 ± 25.82

However, there was great variation among groups. Statistically only the percentage of sows involved in estrus behaviors showed a tendency for increase from day 3 to day 4 (t (4) = -2.63, P = 0.058).

8.4.2 Aggressive behavior

There were no differences in the aggressive interactions among any of the treatments, when comparing either the first mixing for all treatments (EM, LM and PS1), or the EM and LM mixing events to the PS second mixing (PS2, Table 4).

Table 4. LS Means of aggressive interactions observed on days 1 and 2 after mixing in three mixing treatment (per group of 14 sows). Treatments: Early Mixing (EM); Pre-Socialization, first mixing (PS1); Pre-Socialization, second mixing (PS2); Late Mixing (LM).

	Treatment				
Behavior (totals)	EM	PS1	LM	SEM	P
n = 18					
Total aggressive interactions (sum of d1 and d2)	208.50	213.30	212.00	29.20	0.993
Threats per hour (day 1)	12.95	14.47	14.38	1.93	0.825
Head to head per hour (day 1)	1.87	1.77	2.13	0.65	0.918
Head to back per hour (day 1)	0.40	0.28	0.32	0.20	0.913
Percentage (%) of time spent in aggression (day 1)	3.20	2.54	3.55	0.75	0.637
Percentage (%) of time spent in aggression (days 1 and 2)	2.09	1.89	2.34	0.56	0.853
Behavior (totals)	EM	PS2	LM	SEM	P
Total aggressive interactions (sum of d1 and d2)	208.50	190.83	212.00	35.95	0.906
Threats per hour (day 1)	12.95	14.47	14.38	2.40	0.882
Head to head per hour (day 1)	1.87	1.00	2.13	0.60	0.405
Head to back per hour (day 1)	0.40	0.13	0.32	0.18	0.583
Percentage (%) of time spent in aggression (day 1)	3.20	2.21	3.55	0.79	0.477
Percentage (%) of time spent in aggression (days 1 and 2)	2.09	1.76	2.33	0.60	0.814

8.4.3 Sow skin injury and lameness data

Preliminary analysis of skin lesion and lameness data showed there were significant differences in skin injury scores (Fig. 1), with there being no difference in the change in injury scores between EM and LM groups. But both EM and LM treatments had greater change in skin injury scores between pre and post mixing than the PS treatment, with the change in injury score being different between the two PS treatment mixings.

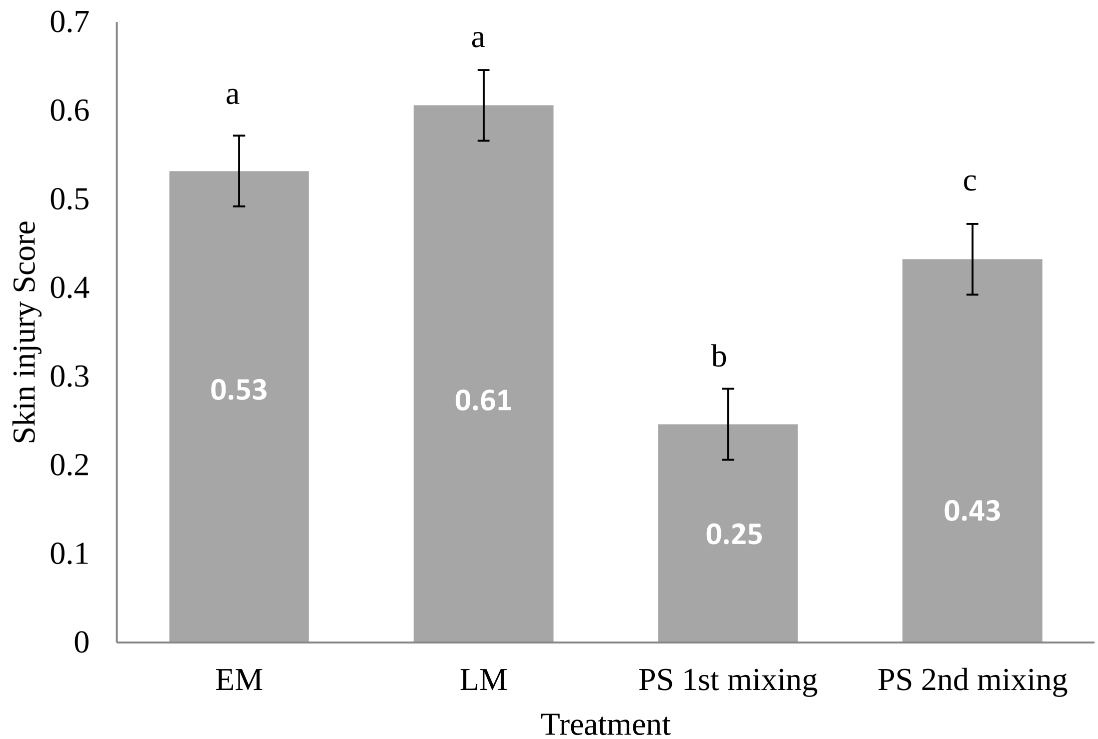

Figure 1. Change in skin injury score at mixing for all treatments. Treatments: Early Mixing (EM); Pre-Socialization, first mixing (PS1); Pre-Socialization, second mixing (PS2); Late Mixing (LM).

There was no difference among treatments in sow gait scores (lameness) observed before and after mixing, or over the course of gestation (data not shown).

8.5 Saliva Cortisol

There were no significant differences among treatments in the levels of saliva cortisol at any of the time points. However, it should be noted the results reported for saliva cortisol were disappointing. In a large number of samples, cortisol levels were below the limit of detection (LOD: 5.5 nmol/L), and this occurred at each time point. The percentage of samples below the LOD per time point measure was: Baseline 72%, 24 hours post mixing: 53% and 72 hours post mixing 63%. This contributed to the difficulty in obtaining meaningful data from these measurements. Means of the saliva cortisol values per treatment are given in table 5.

Table 5. Mean and SD of saliva cortisol (nmol/L) per treatment (four sows sampled/group). Treatments: Early Mixing (EM); Pre-Socialization (PS); Late Mixing (LM).

Measurements	EM	PS	LM
n=	24	24	24
Baseline	6.54 ± 2.58	5.46 ± 0.94	5.21 ± 0.45
24hrs	7.48 ± 2.96	6.87 ± 2.21	.
72 hrs	7.76 ± 3.48	5.66 ± 1.07	.
24hrsWk5	.	5.51 ± 1.09	6.96 ± 3.10
72hrsWk5	.	7.11 ± 5.38	6.88 ± 2.41

Discussion

This study compared the effect of mixing sows into groups at different time points in gestation and found that: when sows were kept in static groups and fed individually there were minimal differences in sow production performance and injury scores, no difference in sow aggression, and no change in sow lameness or salivary cortisol among the three mixing treatments. From these results it can be concluded that mixing sows into groups at weaning is a viable management strategy, as compared to mixing sows at five weeks gestation. It should be noted that the management conditions (sows in static groups and individually fed) likely contributed to this result. Furthermore, the EM treatment actually performed better than the PS and LM treatment, with the highest conception rate, the lowest stillborn rate, and numerically, no gilts repeating after breeding, compared to 8 and 27% of gilts that repeated in the PS and LM groups, respectively. Having sows loose from weaning offers a means to produce pork in a stall free environment, and could be considered higher welfare in terms of the additional behavioral freedom provided to the sow. It appears there may also be production advantages from allowing sows to mix at weaning. This is certainly an area to be explored further. These results shall be discussed in the context of existing knowledge.

9.1 Aggression and productivity

There were no differences in the level of aggressive behavior found among the treatment groups. While no previous studies were found which compared the behavior of sows mixed at weaning to sows mixed later in gestation, several studies have compared mixing sows at other stages of gestation, most commonly comparing pre and post-implantation. Strawford et al. (2008) found no effect of stage of gestation on levels of aggression after mixing in ESF systems. However, other studies did find differences in aggression. Stevens et al. (2015) observed that sows which were individually fed in a cafeteria style feeder and mixed at 35 d post-breeding had reduced frequency and duration of aggressive bouts, and lower cortisol and skin injuries compared to sows that were mixed post-implantation. Despite these differences in aggression, Stevens et al. (2015) found no difference in productivity between the treatments. Knox et al. (2014), studying aggression of sows mixed in an ESF system found that sows mixed at 3 days after insemination or at 35 days gestation had a greater frequency of fighting during the first 24 hours after mixing than sows mixed at 14 days gestation. The differing results of these studies suggest that the level of aggression experienced by sows at mixing depends to some extent on individual herd management, pen facilities and housing system design.

Unlike the current study or that of Stevens et al. (2015), the study by Knox et al (2014) found that productivity was influenced by mixing treatment, with conception rates reduced when sows were mixed on either day 3 or day 14 of gestation, compared to day 35, and lower farrowing rates in sows mixed on day 3 compared to day 35 (Knox et al. 2014). However, in the Knox et al. (2014) study, treatments that showed the highest levels of aggression did not show any corresponding reductions in reproductive performance.

In studies where production performance has been impacted by mixing, the effect may not necessarily be due to aggression, but may rather be an effect of the feeding system. The ability to feed sows individually, and provide the correct amount of feed at key stages of the breeding cycle, may be a necessary feature to ensure reproductive success and high levels of productivity when mixing sows at weaning. Reduced fertility has been attributed to feed intake and body weight gain in sows during gestation (den Hartog et al. 1993; Kranendonk et al. 2007). We believe that a major contributing factor to the production success in the current study was that all the sows were fed individually in free-access stalls. In addition, this may have contributed to the lack of differences in aggression among treatments.

In other studies, reproductive performance has been affected only in systems where the ability of the sow to receive her daily feed at a crucial time in the reproductive cycle (such as ovulation or implantation) may have been compromised. Similar to the results of Knox et al. (2014), Li and Gonyou (2013) found that sows mixed pre-implantation had significantly lower farrowing rates than those mixed post-implantation Both studies were done in ESF systems. While ESF systems provide individual feeding for the sow, unlike the free-access stall system, the ESF creates competition within the group for entry to the feeder and has the potential to negatively impact sow feed intake. Sows that rank lower in the social hierarchy enter the feeder later in the daily cycle (Strawford et al. 2008), and thus may not gain entry to the ESF on a daily basis. Strawford et al. (2008) found sows mixed pre-implantation initiated more aggressive encounters at the entrance to the ESF feeder, than those mixed post-implantation, suggesting that the stage of gestation influenced the sows' willingness to compete for access to the feeder.

These results highlight the importance of correct management of group gestation to prevent reproductive failure, and is important to consider when deciding on when to mix sows. Backus et al. (1997) and Van der Peet-Schwering et al. (2003) both compared sow performance in group housing systems, with sows weaned into and bred in groups. Both studies found housing system effects on reproductive performance, with a greater number of sows returning to oestrus in ESF systems than in free-access stalls (Van der Peet-Schwering et al., 2003), and a longer wean-to service interval for sows housed in ESF and trickle feeding systems than in free-access stalls (Backus et al., 1997). For both studies there was no effect on the total number of piglets born. These authors could not fully conclude what was responsible for the differences in estrus expression, however, it is believed to be linked to effects on sow aggression and feed intake in the ESF and trickle feed systems.

Aside from performance traits, levels of aggression are important to consider in terms of evaluating the effects of management on sow welfare. In the current study, with no difference in the levels of aggression among treatments, it can be concluded that all treatments offer similar welfare for the sow. It should be noted that the levels of aggression observed in all three treatments were low. For example, over the course of two days of observation (average 8.6 h of observation per day), sows spent a maximum of 3.2% of their time in aggressive interactions. This equates to approximately 32 minutes of aggressive interactions over a 17 hour observation period for 14 sows, or 8 seconds/sow/hr. The type of aggressive interaction is also important to consider. Of the interactions observed, the vast majority were threats (one-sided aggression), with relatively few fights. This study defined a threat as a behavior in which a sow makes a threatening gesture, often a head tilt in another sows direction, or a bite, and often without direct contact. A fight on the other hand involved reciprocal contact between sows, pushing and knocking one another with head-to-head or head–to-back contact (O'Connell et al. 2003). Fights are much more likely to cause bodily injury and result in stress, while a threat is a more subtle form of aggression between sows. In fully evaluating housing systems, understanding the nature of aggressive interactions is an important consideration alongside the total number of aggressive interactions. Together, this information provides a clearer picture of the severity of aggression, and gives a better estimate of the impact on sow welfare.

In the PS treatment, sows were mixed twice, once at weaning and again at five weeks gestation. The level of aggression in the PS1 and PS2 mixings did not differ from the other treatments. This suggests that overall there was no benefit of the PS treatment. Production performance was on par with the EM treatment for conception rate, and numbers of piglets born were similar to both the EM and LM treatments. However sows in the PS treatment experienced two bouts of aggression, which together amounted to greater stress and may have put the sows at greater risk of injury than with EM or LM treatments. Sows were only mixed for 2 days initially, and then were held apart for 5 weeks. The 5 week separation period may have been too long to influence mixing aggression; a shorter separation period may have had a more positive effect on reducing aggression in the second mixing, such as sows being placed in the group after insemination. Hoy and Bauer (2005) determined that in sows previously introduced, agonistic interactions are lower when sows are reintroduced, however, the frequency of aggressive interactions increases as the time interval between separation and reunion increases.

9.2 Production performance

Behavioral observations of EM sows within their pen group on days 3 and 4 post-weaning showed that numerically, the number of sows involved, and the amount of estrus behavior displayed rose from day 3 to day 4. The current study took place in pens with fully slatted flooring with large (34 mm) gap openings. Therefore, despite the estrus behavior increasing, it is currently unknown how much this may have increased had sows been housed on a more comfortable and secure flooring. It would be worth to repeat this study in a barn with more suitable flooring to fully determine the merit of mixing sows at weaning to induce heat. Mixing of sows at weaning could be a management strategy to promote, because with the free movement of sows a broader expression of estrus behavior is possible. Sows coming into estrus may release pheromones, advancing and synchronizing estrus within the group (Pearce and Hughes, 1992). The current study did not discover an advancement of heat in the EM groups, as the wean-to-service interval was consistent among the treatments. However, in the EM group, all gilts were bred successfully, as opposed to 8% and 27% returning in the PS and EM treatments, respectively. This therefore, may reflect that EM sows benefitted from being able to express estrus behavior. In addition, the EM group had the highest conception rate, followed by the PS group, with the LM group having the lowest conception rate. Why there was a lower conception rate in the LM group is not fully understood. This treatment matched the standard breeding management of sows in the PSC herd, where the conception rate is typically around 93% (PSC, 2014). There were a number of staff changes during the course of this study which may have contributed; however, this should have affected all treatments similarly.

A further interesting outcome of the EM treatment was the significant reduction in stillborn piglets. This is an exciting result. Previous studies have reported that, compared to sows housed in stalls throughout gestation, sows housed in groups for at least part of gestation have a reduction in stillborn piglets (Lammers et al. 2007; Weng et al. 2009; Chapinal et al. 2010). Results of the current study suggest that allowing sows greater movement during the implantation phase and the initial stages of gestation is enough to reduce stillborns. The mechanism behind this is not known, but we assume it may be due to increased fitness of the sow, or possibly from a better quality of piglets produced, which could be due to better blood circulation and/or distribution of the embryos along the uterine horns arising from increased sow activity during the implantation and initial phase of gestation. The maternal environment is known to influence the placental attachment and function, in turn influencing the growth and function of offspring (see review by Vonnahme et al. 2013). This is an area that would benefit from further research, especially as the industry aims for more viable piglets born per sow per year, as there may be important aspects to consider to reduce pre and post-natal mortality.

9.3 Saliva Cortisol

Measurements of saliva cortisol taken from focal sows in this study indicated that there were no differences in the stress response of sows across the three mixing treatments. This is in agreement with the levels of aggression, which also did not differ. However, a large percentage of samples had saliva cortisol levels below the limit of detection, and thus it is not possible to fully determine how reliable these results are. Levels of saliva cortisol being below the assay’s limit of detection suggest there may have been a problem with interference or sample degradation. The Immulite immunoassay is sold for use with blood serum. An internal study comparing 40 blood and saliva samples from weaner pigs gave an average serum concentration of 182.2 nmol/L and saliva concentration 17.6 nmol/L. This is consistent with the 10x difference observed between blood and saliva matrices found by previous authors (Parrott et al., 1989). Comparing the saliva cortisol values obtained from this study to those found by others, it appears the sows in the current study did not have abnormally low levels of circulating cortisol. For example, Strawford et al. (2008) had a salivary cortisol measurement of 7.65ng/mL for sows mixed pre-implantation. Converted to the units of measurement used in the current study, this is 2.78nmol/L. This confirms it is not unusual for sows to have this lower levels of circulating salivary cortisol. Rather the Immulite assay used in the current study had a limit of detection of 5.5nmol/L, and therefore it appears the assay was not sufficiently sensitive to detect these lower levels of cortisol.

9.4 Lameness and skin injury

The fact that there was no increase in lameness among the treatments, despite the PS treatment receiving two mixings, is consistent with our observation that the mixing aggression that took place was not severe. Especially when considering that the sows in the current study were mixed on fully slatted floors. The lack of difference in lameness among the treatments also demonstrates that having the EM sows loose in groups for the duration of gestation was not detrimental, and that, in this study, the additional activity of sows performing estrus behaviors did not cause any observable problems.

Skin injury was used as a secondary means to estimate mixing aggression. While there were some differences in injury scores among treatments, this resulted from the PS treatment having fewer injuries than the EM and LM treatments. Since overall injury levels were very low we feel this difference is of little importance. In terms of sow welfare, we conclude that all treatments demonstrated low levels of injury at mixing, and thus welfare related to mixing was similar across all treatments.

Conclusion

This study has shown that mixing sows directly into groups at weaning is a viable management strategy, and one that should be explored further. Sows that were mixed at weaning (EM treatment) had performance traits equal to sows mixed at 5 weeks gestation (LM treatment) and performed better in terms of a higher conception rate, and fewer stillborn piglets. The influence of housing sows in groups from weaning should be explored further with regards to these potential production benefits.

Sows that were mixed for 2 days at weaning and then held in stalls until pregnancy confirmation (PS treatment) showed no benefits in terms of production, and also no reduction in aggression at the second mixing. These factors as well as the added inconvenience of extra handling make this treatment less practical than the other treatments studied.

There were no differences in aggression or in lameness due to mixing in any of the treatments studied. Minimal differences in skin lesions were found after mixing, with the lowest levels found in the PS treatment. These results demonstrate that mixing aggression can be minimal when sows are managed in static groups and individually fed, with no need to compete for access to food. These factors should be considered when determining when to mix sows into groups.

Overall, the minimal differences observed among mixing treatments in this study provide a positive message to swine producers. Mixing at weaning or at five weeks gestation are both viable options, and producers can select and optimise the mixing strategy that best suits their management style, herd flow and facilities.

References

Backus, G.B.C, Vermeer, H.M., Roelofs, P.F.M.M., Vesseur, P.C., Adams, J.H.A.N., Binnendijk, G.P., Smeets, J.J.J, Peet-Schwering, C.M.C., van der Wilt, F.J. (1997) Comparison of hour housing systems for non-lactating sows. Research Insitutue for Pig Husbandary, Rosmalen. Report P1 171.

Chapinal, N., Ruiz de la Torre, J.L., Cerisuelo, A., Gasa, J., Baucells, M.D., Coma, J., Vidal. A. and Manteca, X. (2010) Evaluation of welfare and productivity in pregnant sows kept in stalls or in 2 different group housing systems. *Journal of Veterinary Behavior*. **5**, 82-93.

den Hatog, L.A., Backus, G.B.C. and Vermeer, H.M. (1993) Evaluation of Housing Systems for Sows. *Journal of Animal Science*. **71**, 1339-1344.

Hoy, S. and Bauer, J. (2005) Dominance relationships between sows dependent on the time interval between separation and reunion. *Applied Animal Behavior Science*. **90**, 21-30.

Knox, R., Salak-Johnson, J., Hopgood, M., Greiner, L. and Connor, J. (2014) Effect of day of mixing gestating sows on measures of reproductive performance and animal welfare. *Journal of Animal Science.* **92**, 1698-1707.

Kranendonk, G.H. Van der Mheen, H., Fillerup, M. and Hopster, H. (2007) Social rank of pregnant sows affects their body weight gain and behavior and performance of offspring. *Journal of Animal Science*. **85**, 420-429.

Lammers, P.J., Honeyman, M.S., Mabry, J.W. and Harmon, J.D. (2007) Performance of gestating sows in bedded hoop barns and confinement stalls. *Journal of Animal Science.* **85**, 1311-1317.

Li, Y. Z. and Gonyou, H.W. (2013) Comparison of management options for sows kept in pens with electronic sow feeding stations. *Canadian Journal of Animal Science*. **93**, 445-452.

Parrott, R.F., Misson, B.H. and Baldwin, B.A. (1989) Salivary cortisol in pigs following adrenocorticotropic hormone stimulation: Comparison with plasma levels. *British Veterinary Journal*. **145,** 362-366.

Pearce, G.P and Hughes, A.N. (1992) Contact with a sow in estrus or a mature boar stimulates the onset of estrus in weaned sows. *Veterinary Record*. **130**, 5-9.

PSC (2014) Operation’s Report, by Andries, B. Prairie Swine Centre 2013 – 2014 Annual Research Report. A publication by the Prairie Swine Centre. Available at: http://www.prairieswine.com/wp-content/uploads/2010/06/Prairie-Swine-Centre-ARR-13-14.pdf

Stevens, B., Karlen, G.M., Morrison, R., Gonyou, H.W., Butler, K.L., Kerswell, K.J. and Hemsworth, P.H. (2015) Effects of stage of gestation at mixing on aggression, injuries and stress in sows. *Applied Animal Behavior Science*. 165, 40-46.

Van der Peet-Schwering, C.M.C, Kemp, B., Binnendijk, G.P., den Hartog, L.A., Spoolder, H.A.M., Vestegen, M.W.A. (2003) Performance of sows fed high levels of non-starch polysacchardies during gestation and lactation over three parities. *Journal of Animal Science*. **81**, 2247-2258.

Vonnahme, K.A., Lemley, C.O., Shukla. P. and O' Rourke, S.T. (2013) 2011 and 2012 early careers achievement awards: Placental programming: How the maternal environment can impact placental function. *Journal of Animal Science.* **91**, 2467-2480.

Weng, R.C., Edwards, S.A. and Hsia, L.C. (2009) Effect of individual, group or ESF housing in pregnancy and individual or group housing in lactation on performance of sows and their piglets. *Asian-Australian Journal of Animal Science*. **22** (9), 1328-1333.