Effect of familiarity and mixing method on gestating sow welfare and productivity in large dynamic groups[1]

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ABSTRACT: The objectives of this study were twofold: first, to investigate the effects of sow familiarity prior to mixing into a larger dynamic group of gestating sows and, second, to examine the impact of how the sows entered the pen during this mixing event. The cohort of sows was either familiar with each other because of premixing (PMIX) or unfamiliar (UMIX). This PMIX or containment of sows in a stall (UMIX), occurred from weaning until the sows were mixed into the large gestation pen 8 d later. The cohort of incoming sows was introduced either as a batched unit (BAT) or new sows were introduced into the dynamic group singly (IND) though the electronic sow feeder. Lesion severity and quantity score, lameness, and body condition score (**BCS**) were tracked throughout the entire gestation period for 213 sows. Overall, there was little effect of the treatment but a strong impact of parity on the outcomes. Younger animals had significantly higher risk for lesions ($P < 0.001$) and higher risk for more severe lesions ($P < 0.001$) than higher parity animals. Lower parity had an association with the risk of lameness ($P < 0.05$), but it had no significant effect on BCS ($P > 0.05$). The risk of lameness increased on days 15 and 62 compared to weaning ($P < 0.001$). Risk of low BCS decreased on days 62 and 113 relative to scores at weaning ($P < 0.001$). A degree of familiarity by day interaction was present for lesion quantity ($P < 0.001$) and lesion severity ($P < 0.001$). The risk of more lesions was higher in the premixed groups before going into the dynamic group, but equilibrated with the unmixed group after day 11, 3 d in the large dynamic pen. The highest risk for the greatest quantity of lesions peaked at day 11 then declined, but never reached the lowest level again which was measured at weaning. Despite the variability in the welfare measures, there was no significant impact of treatment or parity on sow productivity. In conclusion, our data demonstrate that a period of premixing sows and varying the method of entering sows into the pen did not have a long-term impact on the welfare of the sows or on their productivity.

Key words: dynamic groups, electronic sow feeding, housing, sow, welfare

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INTRODUCTION

Group housing of gestating sows is becoming more commonplace in the swine industry today due to increased public scrutiny of individual housing. There are many alternatives to the gestation crate; however, electronic sow feeding (**ESF**) is the only group housing solution where the producer has the ability to provide individual nutrition for each animal. To optimize space and feeder utilization in ESF barns, many farms use large dynamic groups where a portion of the sows regularly leave the group to go to farrowing and return to the group after breeding. A major challenge is managing aggression during the initial period of hierarchy formation (Giersing and

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Andersen, 1998). Research studies from Europe consistently find premixing sows prior to their introduction into the ESF pen beneficial by enhancing subgroup formation and reducing aggression when later introduced to the larger group (Van Putten and Van De Burgwal, 1990; Durrell et al., 2003). In the studies conducted in North America, familiarity was defined as the proportion of sows that have gestated together previously (Strawford et al., 2008) and specifically premixing sows in order to allow subgroup formation prior to their addition to a large dynamic group has not been studied. The number of introductions of animals into a dynamic group has been suggested to increase aggressive interactions (Jensen et al., 2000), but the approach of mitigating such aggression by introducing animals individually through the ESF stations has not, to the authors' knowledge, been tested. Despite the lack of rigorous testing under North American conditions, premixing of sows and the introduction of individual sows through the ESF station are being tried in the field in the United States as methods to minimize aggression at mixing. The objective of the study is to evaluate whether two different management practices mitigate the problems associated with the introduction of new sows into an existing group. Specifically, this study evaluates the effect of familiarity among sows being introduced into a large dynamic group and the effect of method of introduction into the large dynamic group on welfare measures and the productivity of sows fed by ESFs.

MATERIALS AND METHODS

The Institutional Care and Use Committee of the University of Pennsylvania reviewed and approved the protocol for this study using The Guide for the Care and Use of Laboratory Animals (IACUC Protocol #804656).

Animals and Facilities

The farm used was the New Bolton Center swine research and teaching facility at the University of Pennsylvania School of Veterinary Medicine. A group of 130 gestating sows were housed in a single large dynamic group and fed by two ESFs (Compident VII, Schauer Agrotronics, Prambachkirchen, Austria). Weaned, mated sows were added to the large dynamic group weekly, 8 d postweaning and a similar number of pregnant sows (day 113 of gestation) were moved to farrowing rooms. The pen gave sows a space allowance of 1.86 m^2/sow. The ESF stations turned on at midnight and by 4 p.m. the feeders closed or sooner if all sows had consumed their daily ration. Gilts were housed in a separate pen and not included in the experiment.

Treatments

The experiment used a 2 × 2 factorial arrangement with the degree of familiarity among the new sows as the first factor (DOF) and the method of sow introduction into the established, dynamic group (MOI) as the second factor. These treatments were applied sequentially as the cohort of new sows was either familiar with each other because of premixing (PMIX) or not premixed and unfamiliar with each other (UMIX) from weaning until day 7. On day 8, the cohort of eight incoming sows was introduced either as a batched unit, in which all new sows were introduced into the dynamic group in the ESF pen together (BAT), or individually, in which the new sows were introduced via the ESF station into the dynamic group one by one (IND). Seven replications, that each included one sow cohort of each of the four treatment structures, were completed.

Each replication consisted of four treatment structures PMIXBAT, PMIXIND, UMIXBAT, and UMIXIND. Prior to the start of each replication, the order of the four treatments was randomized by a random number generator. A new structure began weekly. After the sows for all four treatment structures were introduced to the ESF pen, a 2-wk break occurred in which no new experimental sows were added to the ESF pen. Sows not included in the experiment were added during those 2 wks. Following the 2-wk break, the next replication commenced.

On weaning day (day 0), the entire cohort of eight commercially bred PIC 1050 (PIC, Hendersonville, TN) parity 1 or greater sows were exposed to either PMIX or UMIX treatments, and on day 8 to either BAT or IND treatments ($N = 224$, equally divided among seven replications of the four treatment structures). For all replications, the cohort was composed of the sows ready to be bred after weaning. Sows in the UMIX treatment were placed in gestation stalls and housed individually for 8 d from weaning until entering the ESF pen (day 8). Sows in the PMIX treatment were housed together to allow social interaction. The PMIX treatment pen contained 10 full-length stalls, which were closed and only used for feeding and breeding, and a central 3.05 m × 4.9 m area that provided 1.86 m^2/sow. PMIX sows were housed in this way from days 0 to 8, the same amount of time as the UMIX group was in stalls after weaning.

On days 4 through 6, sows in both PMIX and UMIX treatment structures were checked in crates for estrus using a boar. After the onset of estrus, each sow was artificially inseminated in the stall once a day for up to 3 d until she was no longer in standing estrus. Sows in PMIX treatment were re-released into the pen each day after feeding, heat checking and insemination. Those sows that were not bred by day 7 were not included in the study. The total number of sows that were enrolled in the study was 213 after the exclusion of those sows not bred by day 7 (Table 1).

On day 8, new sows were individually marked with livestock markers for identification. The total group was six to eight sows depending on the number bred. The sows were brought to the pen and entered into the large gestation pen as either IND or BAT. Those sows introduced as a BAT received their daily ration at 08:00, in the stalls in the premix area, prior to the first group entering the pen at 13:00. For IND cohorts, the same one of the two ESF stations was temporarily re-gated so that the entrance faced the alleyway. Sows were left in the alleyway and entered the ESF station from the alleyway, received their daily feed allotment in the ESF station, and exited from the ESF station into the dynamic group pen. This process took ~10 min per sow and started at 13:00.

Diets

Sows were fed a standard corn–soy diet meeting NRC (2012) standards. The metabolizable energy for the diet was 3,197.2 kcal/kg, standardized ileal digestible (SID) lysine 0.64%, calcium 0.91%, available calcium 1.05%, phosphorous 0.61%, and the available phosphorous 0.51%. They were fed on a feed curve dependent on their body condition score (**BCS**) on day 8 (Table 2). After BCS assessment on day 62, adjustments were made to the sow's feed curve if needed. Sows that were BCS 3 were fed 1.81 kg with a bump up to 2.72 kg from 90 d until loading into farrowing. The curve was adjusted up or down depending on sow body condition. Following data collection 113 d after weaning, the sows were moved into individual stalls in the farrowing facility. Sows that returned to estrus during the experiment were removed from the group pen for rebreeding.

Productivity Measures

The farrowing rate of the sows for each treatment structure within a replication was calculated as the number of sows that farrowed with the study group/the number of sows bred × 100. The total litter size and the number of live borns, and stillborn pigs were recorded. Birth weights were recorded for the live pigs in each litter. Whether a sow was bred by 5 d postweaning was calculated by finding the difference between the weaning date and the first insemination date for both PMIX and UMIX sows.

Welfare Measures

Lesions were assessed on day 0 (weaning), day 7 (day before mixing into the large dynamic group), day 8 (on the day of mixing into the large dynamic group at 17:00 after mixing), days 11, 15, 20, 34, 48, 62, 76, 90, and 113 (loading into farrowing). Animals were scored for body lesions using a standardized scale measuring severity and quantity of lesions in three body regions: anterior (cranial to the caudal aspect of the shoulder), side (between

Table 1. Demographics of the 213 study sows at allocation to treatment

	Degree of familiarity		Method of introduction	
	PMIX[3] (n = 111)	UMIX[4] (n = 112)	IND[5] (n = 112)	BAT[6] (n = 111)
Parity[1]	3.6 ± 2.0	3.7 ± 2.1	3.6 ± 2.0	3.7 ± 2.1
Body condition score (BCS)[2]	3 ± 1	3 ± 1	3 ± 1	3 ± 0
Lesion Quantity[2]	1 ± 0	1 ± 0	1 ± 0	1 ± 0
Lesion Severity[2]	1 ± 0	1 ± 0	1 ± 0	1 ± 0

BCS is from 1 to 5, where 1 is emaciated and 5 is overly fat. Lesion quantity score is from 1 to 5 where 1 < 5 scratches and 5 ≤ 35 scratches. Lesion severity score is from 1 to 3 where 1 is thin and shallow scratches and 3 is wide and deep scratches.

[1]Reported as mean ± SD.

[2]Reported as median ± interquartile range.

[3]Premixed animals were allowed a period of interaction for 7 d postweaning prior to entering into the large gestation pen.

[4]Unmixed animals were housed in a stall for 7 d postweaning prior to entering into the large gestation pen.

[5]Individually introduced animals entered the large gestation pen through the electronic sow feeding (ESF) station.

[6]Batch introduced animals entered directly into the large gestation pen as a group.

the caudal shoulder and cranial hip), and posterior (from the cranial hip caudally). The severity of each lesion was scored from 1 to 3 based on the size and depth of the lesion with 1 being a less severe lesion and 3 being the most severe. The score recorded for each region was the score from the highest scoring, most severe, lesion. The quantity of the lesions was counted and given a standardized score from 1 to 5 for each region (Table 3).

Lameness was judged on a scale from 0 to 3 adapted from the Feet First Swine Locomotion Scoring System (Zinpro Corp., Eden Prairie, MN) (Table 4). Lameness was assessed at day 0 (weaning), day 7 (day before mixing), days 15, 62, and 113 (loading into farrowing). When animals were removed from the pen for scoring on day 0 (weaning), day 7 (day before mixing), days 62 and 113 (loading into farrowing) they were assessed on a solid concrete floor and watched at the walk for at least 10 m.

BCS was done according to industry standard practice adapted from the Pork Quality Assurance Plus Program (https://lms.pork.org/Tools/View/pqa-plus/program-materials; accessed January 2018, p. 41). Sows were assigned scores from 1 to 5 based on their appearance from thin to fat and the ability to palpate certain bony landmarks (Table 2). Body condition was assessed at day 0 (weaning), day 7 (day before mixing in the large dynamic pen), day 15 (1 wk after mixing in the large dynamic pen), days 62 and 113.

Table 2. BCS adapted from the Pork Quality Assurance Plus Program

Score	Condition	Detect of ribs, backbone, “H” bones, and pin bones
1	Emaciated	Obvious
2	Thin	Easily detected with palm pressure
3	Ideal	Barely felt with firm palm pressure
4	Fat	None
5	Overly fat	None

Sows were assigned scores from 1 to 5 based on their appearance from thin to fat and the ability to palpate certain bony landmarks.

Table 3. Description of lesion scoring methodology for lesion quantity and lesion severity

Category	Score	Description
Severity	1	Thin (<2 mm wide) and shallow; epidermis may be broken with mild surface inflammation
	2	Moderately deep cuts (2 to 4 mm wide); epidermal and dermal layers may be broken with moderate inflammation
	3	Occurrence of a wide (>4 mm) or deep cuts; dermal layers broken with severe inflammation
Quantity	1	≤ 5 cuts
	2	6 to 10 cuts
	3	11 to 20 cuts
	4	21 to 30 cuts
	5	>31 cuts

Statistical Analysis

All statistical analysis was done using STATA version 15 (StataCorp LP, College Station, TX). To determine whether to retain a variable in the final multivariate model, univariate methods were used and the factor retained if $P < 0.35$ (Niranjan et al., 2005). The sow was the experimental unit for statistical analysis. In this 2 × 2 factorial arrangement both factors, MOI and DOF, and their interaction served as fixed effects. Score on day 0 was included as a linear covariate for lesion quantity, lesion severity, lameness, and BCS models. Sow served as the random effect unless otherwise noted. A *P*-value of <0.05 was treated as significant.

Farrowing success was analyzed as a binary outcome using a mixed effect logistic regression model with degree of familiarity and method of introduction as fixed effects and breeding group as the random effect. Total born was defined as the sum of live born, still born, and mummies. Birth weight was calculated for those piglets that were born alive. Total born and birthweight were analyzed by mixed effect generalized linear model where the family was Gaussian and the link function identity. The MOI, DOF, farrowing room (pens versus stalls), and parity served as fixed effects. Sow served as the random effect for total born, and replicates the random effect for birthweight. Live born was analyzed by generalized linear model with a binomial

Table 4. Locomotion score adapted from Feet First (Zinpro Corp.)

Locomotion Score	Description
0	Sow moves easily with little inducement. She is comfortable on all her feet
1	Sow moves relatively easy, but a change in gate is visualized in at least one leg. She still moves easily from site to site in the barn and is not considered lame
1.5	Lameness is involved in one or more limbs. The sow exhibits compensatory behaviors such as dipping her head or arching her back
2	There is a real reluctance to walk and bear weight on one or more legs. It is difficult to move her from place to place on the farm
3	Sow is not bearing weight on one or more limbs. She may be unable to walk

distribution, grouped by total born, and the link function was logit. The model included both factors and their interaction, farrowing room, and parity as fixed effects. Sow served as the random effect. A Kruskal–Wallis test was used to test the effect of DOF on whether a sow was bred by day 5 postweaning.

A mixed effect ordinal regression model was used to model lesion quantity, and lesion severity. The lesion quantity model included DOF, MOI, and their interaction, the interaction of DOF and day postweaning, day postweaning, region, and parity as fixed effects. The lesion severity model included DOF and MOI as well as their interaction, the interaction of both DOF and MOI with day postweaning, the day postweaning, region, and parity as fixed effects. A Bonferroni correction was used to account for multiple comparisons between parities, and DOF and MOI on different days. The correlation between lesion severity and lesion quantity was done using a spearman rank sum correlation.

Due to the low number of animals scored as a 2 (n = 18), and no animal scored as a 3, lameness was condensed to lame (score ≥ 1.5) or not lame (score <1.5). Lameness was assessed with a mixed effect binomial regression model including DOF, MOI, the interaction of DOF and MOI with the day postweaning, the day postweaning, and parity as fixed effects and the sow as random effects. A Bonferroni correction was used to account for multiple comparisons between multiple days and parities.

BCS was analyzed with a mixed effect ordinal regression model including DOF, MOI, the interaction of DOF and MOI, the interaction of DOF and MOI with the day postweaning, parity, and day postweaning as fixed effects. A Bonferroni correction was used to account for multiple comparisons between days, DOF and MOI on different days, and parities. Throughout the study only scores of 2, 3, and 4 were recorded.

RESULTS

Sow Productivity

Farrowing rate was 88% across all 213 animals bred in the trial. There was no association between DOF and farrowing success where 95 out of 111 PMIX sows and 90 out of 112 UMIX sows farrowed (P = 0.10). There was also no association between MOI and farrowing success where 96 out of 112 BAT sows and 89 out of 111 IND sows farrowed (P = 0.09). There was no association found between DOF or MOI on total born, live born, or litter birthweight (Table 5). There was also no association between parity and litter productivity measures: total born (P = 0.31), live born (P = 0.08), and mean litter birthweight (P = 0.13). Assessing whether or not a sow was bred by day 5, there was no increased risk associated with premixing where the number of sows bred by day 5 was 103 out of the 111 PMIX sows and 100 out of 112 UMIX sows (P = 0.36).

Welfare Measures

Lesions. *Lesion quantity*: There was no effect of method of introduction on lesion quantity (P = 0.07) (Table 6). For the quantity of lesions, there was a significant interaction between

Table 5. Farrowing productivity measures by degree of familiarity and method of introduction

	Degree of familiarity				Method of introduction			
	PMIX[1]		UMIX[2]		IND[3]		BAT[4]	
	LSM5	SE6	LSM5	SE6	LSM5	SE6	LSM5	SE6
Total born[7]	14.3	0.43	14.6	0.46	14.7	0.41	14.2	0.47
Live born	12.9	0.21	13.1	0.20	13.0	0.19	13.1	0.21
Litter birth weight[8] (kg)	21.1	0.72	21.1	0.72	21.2	0.72	21.0	0.72

No significant differences were found at $P < 0.05$.

[1]Premixed animals were allowed a period of interaction for 7 d postweaning prior to entering into the large gestation pen.

[2]Unmixed animals were housed in a stall for 7 d postweaning prior to entering into the large gestation pen.

[3]Individually introduced animals entered the large gestation pen through the ESF station.

[4]Batch introduced animals entered directly into the large gestation pen as a group.

[5]Least-square mean.

[6]Standard error.

[7]Calculated as the sum of still born piglets, mummies, and live born piglets.

[8]Combined weight of all of the live born piglets in the litter.

Table 6. Difference between methods of introduction, degree of familiarity by day interaction where day is the number of days postweaning, parity, body region, and score on day 0 on lesion quantity score and lesion severity score

	Method of introduction[1]		Degree of familiarity by day interaction[2]								Parity[3]												Region[4]				Score on Day 0[7]	
			UMIX day 0		UMIX day 7		UMIX day 8		UMIX day 11		2		3		4		5		6		7		Side[5]		Posterior[6]			
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	REG8	SE
Lesion quantity[9]	0.81	0.65 to 1.0	1.3	0.37 to 4.6	0.01[a]	0.01 to 0.05	0.63[a]	0.04 to 0.20	1.1	5.4 to 2.0	0.20[a]	0.17 to 0.26	0.17[a]	0.14 to 0.23	0.12[a]	0.08 to 0.16	0.06[a]	0.04 to 0.09	0.05[a]	0.03 to 0.07	0.03[a]	0.02 to 0.05	0.38[a]	0.33 to 0.43	0.18[a]	0.16 to 0.21	0.09	0.05
Lesion severity[10]	0.77	0.62 to 1.4	0.86	0.40 to 1.8	0.02[a]	0.01 to 0.05	0.48[b]	0.25 to 0.96	1.7	0.72 to 3.9	0.59[a]	0.47 to 0.74	0.42[a]	0.33 to 0.53	0.40[a]	0.30 to 0.54	0.29[a]	0.22 to 0.40	0.28[a]	0.21 to 0.37	0.20[a]	0.14 to 0.28	0.96	0.86 to 1.1	0.60[a]	0.53 to 0.68	0.15	0.08

[a]Significantly different from the reference category, $P < 0.001$.

[b]Significantly different from the reference category, $P < 0.05$.

[1]Odds ratios reported for sows entered as batch into the large gestation pen compared to those entered as individuals through the ESF.

[2]Odds ratios reported for unmixed sows on the indicated days compared to sows allowed a period of premixing for 7 d postweaning on the same day.

[3]Odds ratios reported for parities indicated compared to parity 1 sows.

[4]Odds ratios reported for each region compared to the anterior region, which is cranial to the caudal aspect of the shoulder.

[5]Side region is between the caudal shoulder and cranial hip.

[6]Posterior region is from the cranial hip caudally.

[7]Included in the model as a continuous variable.

[8]Regression coefficient.

[9]Lesion quantity score is from 1 to 5 where 1 < 5 scratches and 5 ≤ 35 scratches (see Table 3 for detailed description of all score levels).

[10]Lesion severity score is from 1 to 3 where 1 is thin and shallow scratches and 3 is wide and deep scratches (see Table 3 for detailed description of all score levels).

familiarity and day postweaning ($P < 0.001$). On day 7, UMIX animals in stalls were at lower risk for lesions than PMIX animals that were not in stalls ($P < 0.001$); on day 8, the day of mixing into the large dynamic pen, UMIX sows were still at lower risk for more lesions ($P < 0.001$), then, on day 11 postweaning, 3 d after mixing in the large gestation pen, there was no association with lesion quantity and DOF ($P > 0.05$) (Table 6).

The peak risk for high lesion quantity score was at day 11 postweaning for the PMIX sows relative to day 0 (OR = 778.5; CI = 281.6 to 2152.2; $P < 0.001$). The risk for UMIX sows peaked at day 20 postweaning compared to day 0 (OR = 538.3; CI = 211.5 to 1,370.4; $P < 0.001$). The risk of lesions on day 113 compared to day 0 was significantly higher for both PMIX sows (OR = 47.3; CI = 17.0 to 131.1; $P < 0.001$) and UMIX sows (OR = 30.5; CI = 11.9 to 78.3; $P < 0.001$).

There was a significant association between parity and lesion quantity with higher parity being protective ($P < 0.001$). All parities were at lower risk when compared to parity 1 animals (Table 6).

The anterior body region was at higher risk for lesions compared to the middle region or the posterior region (Table 6).

Lesion severity: There was a highly significant correlation between lesion severity and lesion quantity ($r = 0.59$, $P < 0.001$). There was no association between MOI and lesion severity score ($P = 0.77$). Like lesion quantity there was a significant interaction between DOF and day postweaning ($P < 0.001$). There was a decreased risk of severe lesions for UMIX sows in stalls on day 7 postweaning compared to PMIX animals that were not in stalls, continuing on day 8, when the sows were mixed into the large gestation pen, the UMIX animals were still at lower risk for severe lesions ($P < 0.05$), then on day 11, 3 d post mixing into the large dynamic pen, there was no longer an association between DOF and lesion severity score ($P > 0.05$) (Table 6).

The highest risk of more severe lesions compared to day 0 was at day 11 postweaning for both the PMIX sows (OR = 148.0; CI = 70.2 to 311.9; $P < 0.001$) and the UMIX sows (OR = 285.4; CI = 125.9 to 647.0; $P < 0.001$). The risk of more severe lesions on day 113 compared to day 0 was significantly higher for both PMIX sows (OR = 9.4; CI = 4.9 to 18.3; $P < 0.001$) and UMIX sows (OR = 8.8; CI = 4.5 to 17.6; $P < 0.001$).

There was a significant overall association between parity and lesion severity where higher parity was protective ($P < 0.001$). When each parity was compared to parity 1 sows, there was a significantly lower risk for severe lesions in the higher parity sows ($P < 0.001$) (Table 6).

There was a significant association between region and lesion severity ($P < 0.001$). There was an increased risk for severe lesions in the anterior region compared to the posterior region ($P < 0.001$) but not the side region ($P = 0.54$) (Table 6).

Lameness

There was no association between lameness and DOF ($P = 0.64$) and no effect of MOI ($P = 0.74$). On day 0, weaning, 8% of animals were scored as lame. On day 7, 15% were lame, day 15, 22% and the percent of lame animals peaked at day 62 after weaning, with 30% of animals scored as lame. The risk of lameness then declined by the time the sows were loaded into farrowing on day 113 with 17% scored as lame. On days 15 and 62, the risk of lameness was higher compared to weaning ($P < 0.001$) (Table 7). There was a significant association between lameness and the lameness score at day 0 ($P < 0.001$) (Table 7).

There was a significant association between parity and lameness ($P < 0.05$). When compared to parity 1 sows, parity 6 sows were at lower risk for lameness (OR = 0.23; CI = 0.07 to 0.76; $P < 0.01$).

Body Condition Score

There was no association found between BCS and DOF ($P = 0.16$), or MO1 ($P = 0.43$). As well as a significant effect of day 0 BCS score ($P < 0.001$), there was a significant decrease in the risk of low BCS on days 62 and 113 compared to weaning (Table 7). There was no association seen between parity and BCS ($P = 0.14$).

DISCUSSION

Aggressive encounters associated with the introduction of new animals into dynamic groups can lead to lameness and other injuries (Durrell et al., 2003) that threaten the welfare and productivity of these sows. Thus, one major challenge is managing aggression during the initial period of hierarchy formation (Giersing and Andersen, 1998). Levels of aggression may decrease in static groups once a social hierarchy is established (Anil et al., 2006), but in dynamic groups the ongoing introduction of new sows may lead to continued aggressive interactions as sows attempt to re-establish a new social hierarchy (Simmins, 1993; Weng et al., 1998; Anil et al., 2006). Though no direct

Table 7. Differences between degree of familiarity, method of introduction, day postweaning where day 0 is weaning and day 7 is the day before mixing in the large gestation pen, and score on day 0 on BCS and lameness

	Degree of familiarity[1]		Method of introduction[2]		Day Postweaning[3]								Score on Day 0[4]	
					Day 7		Day 15		Day 62		Day 113			
	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds ratio	95% CI	Odds Ratio	95%CI	REG[5]	SE
Lameness[6]	0.76	0.24 to 2.4	0.83	0.27 to 2.5	2.3	0.8 to 6.5	4.6[a]	1.7 to 12.1	8.1[a]	3.1 to 21.4	2.9	1.0 to 8.4	2.3[a]	0.38
BCS[7]	0.52	0.21 to 1.3	1.4	0.58 to 3.5	1.5	0.66 to 3.2	0.90	0.41 to 2.0	9.6[a]	4.0 to 23.0	23.9[a]	9.5 to 60.2	5.4[a]	0.39

[a]Significantly different from reference category $P < 0.001$.

[1]Odds ratio reported for unmixed sows compared to sows allowed a period of premixing for 7 d postweaning and prior to entry into the large gestation pen on day 8.

[2]Odds ratio reported for sows entered into the large gestation pen in a batch compared to those entered individually through the ESF.

[3]Odds ratios reported for days indicated compared to day 0 (weaning).

[4]Included in the model as a continuous variable.

[5]Regression coefficient.

[6]Sows were categorized as not lame (score < 1.5) or lame (score ≥ 1.5) (refer to Table 4 for description of score for each category).

[7]BCS was on a scale of 1 to 5 where sows were scored 1 for emaciated and 5 for overly fat (see Table 2 for detailed description of each score).

measure of aggressive interaction was attempted in this study, lesion scores have been shown to correlate with the number of aggressive interactions following sow grouping (Barnett et al., 1993) and thus lesion quantity and severity were used as proxies for aggression.

Several factors influence the degree of aggressive behavior performed during group formation in ESF pens, but their effects often vary among research studies. Increasing the percentage of new sows entering a dynamic group has been reported to both increase (O'Connell et al., 2004) and decrease (Anil et al., 2006) aggressive interactions. Likewise, the majority of fighting has been reported to occur both between new and resident animals (Moore et al., 1993) and also between new animals alone (Durrell et al., 2003; Remience et al., 2008). In several studies in Europe, premixing sows were found to allow the formation of subgroups which then reduced aggression when sows were mixed into a larger group of sows (Van Putten and Van De Burgwal, 1990; Durrell et al., 2003).

While the premixing of sows and the introduction of individual sows through the ESF are being tried in the field in the United States, they are not widely accepted and had not previously been rigorously tested under conditions reflecting North American swine production (e.g., housing, genetics, feed, etc.). Thus, the premixing of sows prior to introduction to the dynamic group and introduction of animals via the ESF feeder into dynamic groups are the focus of this study. This study is also unique since it looks at the impact of the dynamic group on a large group of animals across their entire gestation period for multiple animal-based measures of animal welfare. Day has an impact on the outcomes measured indicating that measurements taken at single time points are not representative of the entirety of an animal's experience in a dynamic group.

In this study, regardless if animals had been premixed, the risk for higher lesion quantity and greater lesion severity continued to rise post mixing into the dynamic group (day 8 after weaning). Lesion quantity risk peaked at day 11 for PMIX and UMIX sows, whereas the risk of more severe lesions peaked at day 11 for PMIX sows and day 20 for UMIX sows. The risk declined for both groups after day 20 post weaning but on day 113 when animals returned to farrowing accommodations, they were still at higher risk relative to weaning. This is longer than the period suggested by data that showed aggression resolved within 3 d (Oldigs, 1992) or a study in a dynamic group of 40 sows where aggression diminished in 10 d (Van Putten and Van deBergwal, 1990). It is, however, a shorter period of aggression than another study where lesion scores stabilized by day 28 (Arey,1999). This long period of aggressive interactions is likely why the differences in mixing strategy, as either an individual or a batch, had no effect. Much like chemical interventions at mixing (Barnett et al., 1993), boar presence at mixing (Barnett et al., 1993), or mixing in the dark (Barnett et al., 1994), aggressive interactions over a longer time course were not altered by animals entering through the feed stations. There was no significant interaction between the method of introduction and the day postweaning, nor was there a significant association between the method of introduction and lesion quality or lesion quantity. This suggests that there was no association between lesion quantity or severity and animals entering through the feed stations. Finally, by day 11 post weaning, or 3 d in the large gestation pen, there were no differences in risk for lesion quantity or severity scores regardless of whether sows experience premixing. Taken together, these results suggest that the familiar sows were subjected to an additional 7 d of increased skin lesions compared the unfamiliar animals that were not premixed and remained in stalls postweaning. However, sows that were not premixed continued to be at higher risk for more severe lesions for longer. The overall impact on welfare of premixing is less clear as the increase in lesions has to be weighed against the increased mobility and expression of natural behaviors afforded the premixed group during the postweaning period.

By day 7, the end of the premixing period, premixed animals had significantly higher number of lesions than the unmixed sows that remained in stalls. This is logical since premixed animals were allowed to interact and therefore those premixed groups had higher lesions than the unmixed group. However, in contrast to other studies that showed that premixing decreased aggression and injuries post mixing into a larger group, this study did not show a difference. In studies where decreases in aggressive events were demonstrated, the premixing period was 35 d (Durrell et al., 2003) and 12 d (Van Putten and Van De Burgwal, 1990). This is longer than the 7 d applied here to the premixed group and, in the case of the 35-d period in the Durrell study, a different stage of gestation. It could therefore be that the period of familiarization applied here was not long enough or that at later stages of gestation, sows engage in fewer aggressive encounters. Several studies show that when sows are maintained in gestation stalls until later stages of gestation they sustain fewer lesions than animals mixed earlier in gestation (Knox et al., 2014; Stevens et al., 2015). Whether this is due to changes in hormones related to pregnancy has not been determined.

This lack of a significant treatment impact of premixing does not mean, however, that familiarity did not have an impact on aggression. Since this is a large dynamic group, a 7th parity sow for example, would not have been in the pen as a gilt, but then would have been in the pen for six previous gestation periods, presumably becoming acquainted with other sows in the herd. Parity had a significant association with lesion quantity and severity. Older animals had significantly lower risk of lesions and lower risk of severe lesions. This seems to indicate that higher parity animals are engaged in fewer aggressive encounters but could mean that older animals are just as aggressive, or potentially more aggressive, but engage in encounters where they are less likely to sustain lesions. This lower risk of lesions could also be due to familiarity. Other studies have shown that sows can remember other sows for up to 6 wk (Ewbank and Meese, 1971) so a sow leaving for lactation would not rule out the possibility that she is familiar with other sows when she returns to the pen. Another study showed that at mixing only 7% of the fights were between animals that had been housed together during the previous gestation (Arey, 1999). There is a strong indication that animals that are familiar with each other, due to being housed together during previous gestations, are less likely to interact aggressively. In this study, however, we cannot rule out that the decrease in aggression is related to size or age.

The degree of familiarity and method of introduction did not have an impact on reproductive productivity and met current industry norms for farrowing rate and total born. Recent studies showed that grouping sows directly after weaning and performing estrus detection and breeding in group pens resulted in fewer sows inseminated by day 5 compared to sows kept in stalls (Rault et al., 2014). We did not see a significant impact of mixing sows on breeding performance most likely because of the use of the free access stall during estrus detection and breeding. Therefore, there was no suppression of estrus behaviors compared to the groups continuously housed in stalls.

In a previous study in growing pigs, lesions in the anterior region of the pig were found to relate to pigs engaging in reciprocal fighting, whereas lesions in the caudal regions were related to bullying (Turner et al., 2006). Across all treatment groups, sows had a higher risk for lesions in the anterior region compared to the side and posterior region. There was also a higher risk for more severe lesions in the anterior and side regions compared to the posterior region. This suggests that more of the lesions they sustained were related to engaging in reciprocal fighting than from being bullied. There was no parity by region interaction, indicating that we did not find a link between parity and engagement in bullying compared to reciprocal aggressive interactions.

BCS on day 0 had a significant effect on BCS. This is important as weight loss during lactation in parity 2 and greater animals lead to a decrease in reproductive performance (Thaker and Bilkei, 2005). As in other studies (Arey, 1999), the day in the pen had a significant effect on BCS where the risk of having a low BCS declined from days 0 to 113 when animals were loaded into farrowing. ESFs are designed to feed sows to condition, and in this case, BCS was at an optimal level when animals were removed from the pen for their next lactation.

The prevalence of lameness in our study varied over the course of the gestation period. It peaked at 30% of sows at 62 d post weaning or 54 d in the dynamic group. A separate study that looked weekly at lameness in a group of sows on an ESF farm, showed a similar pattern across gestation with a peak in lameness at 8 wk in gestation and then a decline until loading into farrowing (Kroneman et al., 1993). In order to compare to other studies then it is important to compare at the same time point in gestation. Several studies measure lameness when moving sows to farrowing at which point in our study the prevalence was at 16.8%, significantly lower than at the peak. A survey of farms in Belgium using ESF stations measured the prevalence of lameness just prior to parturition and in those herds it ranged from 2.4% to 23.1% (Pluym et al., 2011). Another study found a 26.2% prevalence of lameness (Anil et al., 2007) and another, 22.9% prevalence (Zurbrigg and Blackwell, 2006). These studies indicate a large range of prevalence in lameness in group housed sows and the data from this study is consistent with previous findings.

Overall, lesions are indicative of sows facing aggressive interactions with other sows, and those with more lesions, and more severe lesions, likely have lower welfare. In this study, we see that younger animals have more lesions and maintain them for longer than older animals. This indicates that adaptation to the pen is not a rapid process but rather one that takes place over several parities. Even over the course of a single gestation, the amount of time in the pen has a significant effect on the number and severity of lesions, the likelihood of lameness, and the BCS of the sow. Notably, despite the increased lesions after introduction to the pen, productivity was not negatively impacted, nor did we see a negative production impact of premixing the sows during breeding.

In conclusion, this study showed a potential negative aspect of a premixing period as sows were subjected to a longer period of time where they were at risk of sustaining skin lesions. Further studies are required to understand how the negative welfare aspects of skin lesions are counterbalanced by the welfare benefits of increased freedom of movement, and expression of natural behaviors, afforded sows during premixing. Producers may want to enter sows into the pen using the ESF stations to verify the functionality of RFID tags, feed them on the day they enter the pen, or other reasons of convenience. The data produced here would not discourage such practices, as it did not show any impact of such an intervention on our animal-based measures of welfare. Finally, our data demonstrates that parity and duration of the time in the pen had effects on lesion quantity and severity as well as lameness score suggesting that younger animals were most susceptible to any aggression that occurs post mixing into the dynamic group, as well as throughout the remainder of gestation.

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