THE IMPACT OF GESTATION SOW HOUSING SYSTEM (INDIVIDUAL VS. GROUP) ON THE REPRODUCTIVE PERFORMANCE OF SOWS & THE EFFECT OF FARROWING PEN SIZE ON PRE-WEANING MORTALITY.

BY

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THESIS

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ABSTRACT

Section 1: The effect of gestation sow housing system on sow performance was evaluated in a study carried out on a commercial breed-to-wean facility. A Randomized Complete Block Design was used to compare 2 treatments, Individual and Group (8 females/pen) housing. The experimental unit was individual animal and a replicate was 16 females (1 group of 8 and 8 individually-housed). A total of 1325 females were allotted to treatment to produce 1695 individual records. Data was recorded for parity 0 and parity 1 females from allotment into gestation housing treatment (approximately day 35 of gestation) until assigned back into the respective housing treatment.

Sow litter performance, reproductive traits, body weight and body condition score did not differ (P > 0.05) between Gestation Housing treatments. However, females housed in groups had a lower ($P < 0.05$) farrowing rate (3.9 percentage units), and a higher ($P < 0.05$) piglet pre-weaning mortality (1.2 percentage units) and sow removal rate (5.7 percentage units) than those housed in individual stalls. This study will follow females through the 5th parity and the additional data will help understand the effect of housing treatment over time on litter performance, reproductive traits, BCS, and body weight variables.

Section 2: The effect of farrowing pen size (in pens with farrowing crates) on pre-weaning mortality was evaluated in a study carried out on a commercial breed-to-wean facility. This study used animals that were part of the gestation sow housing study (Section 1 above). A Randomized Complete Block Design was used to compare 2 treatments, Standard (pen width = 1.52 m) and Increased (pen width = 1.68 m) pen size. The experimental unit was individual sow and litter and replicate was equal to 2 sows with litter. A total of 526 bred females were allotted to treatment. Data were recorded on litter performance variables.

The Increased pen size treatment had a greater ($P < 0.05$) total number of piglets born per litter (0.5 piglets) and showed a tendency for a greater ($P < 0.10$) litter size after cross-fostering (0.4 piglets). The Increased pen size had a greater ($P < 0.05$) number of piglets weaned per litter (0.4 piglets). Ideally litter size would be similar across the 2 treatments to make it relatively easy to interpret any treatment effects on piglet mortality and the number weaned per litter. Pre-weaning mortality would be the best variable to evaluate the effect on farrowing pen size treatments and this was not different ($P > 0.05$) between the two treatments which suggests that there was no benefit for the increased farrowing pen size. The study was carried out with relatively young (mainly parity 0 and 1) and relatively small animals and the study is on-going to collect data on older and bigger animals to evaluate the effect of farrowing pen size on pre-weaning mortality over time.

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CHAPTER 1: LITERATURE REVIEW

SECTION 1: GESTATION SOW HOUSING SYSTEM

INTRODUCTION

The type of sow housing system (Individual crate or Group housed) used in gestation has been a controversial topic, making it essential for research to be conducted to quantify the impacts on reproductive performance and welfare for the sows in each system. Since 2013, European Union legislation (1.1.2013 EU) abolished the use of stall-housing system for pregnant sows from the 4 weeks after service until the week prior to farrowing. This legislation also required a minimum floor space allowance of 2.25m^2/sow. Since this EU legislative directive, several studies have been performed to evaluate the advantages and disadvantages of housing sows in groups rather than in individual stalls. The results from these studies have been highly variable, with some studies showing an improvement in performance of sows housed in individual stalls with others showing an advantage in terms of performance for sows housed in groups. In addition, several studies have shown no effect of individual compared to group housing on sow performance. In many situations, the easiest and least expensive approach to changing from housing sows in individual crates to housing sows in groups is to convert the existing crates to pens. However, there has been limited research evaluating the effects of housing sows in small groups in small pens, which have been retrofitted from existing individual crates, compared to housing them in individual crates and carried out under commercial conditions.

The following literature review summarizes previous research evaluating the effect of sow gestation housing system on litter performance, reproductive traits, removal rates, and body weights and condition score.

SOW LITTER PERFORMANCE

A total of 11 studies were found that evaluated the effects of gestation housing system on sow and litter performance and these are summarized in Table 1a & 1b. Most studies found no effect of housing sows in groups or individual pens on litter performance. The number of total born piglets per litter was not different ($P > 0.05$) between group and individually housed sows in 7 out of 8 studies. The number of piglets born alive per litter was not different ($P > 0.05$) between gestation housing system treatments for 10 out of 11 studies. The number of piglets born dead per litter was not different ($P > 0.05$) between gestation housing system treatments for all 7 studies that reported this variable. The number of piglets born mummified was not different ($P > 0.05$) between gestation housing system treatments for 5 out of 6 studies. The number weaned per litter was not different ($P > 0.05$) between housing system treatment for 4 out of the 5 studies that reported this variable. Pre-weaning mortality rate was not different ($P > 0.05$) between housing systems in the two that reported this measure. Litter birth weight and litter weaning weight was not different ($P > 0.05$) between housing systems for 4 out of the 5 studies that reported these measure.

The one study that reported a significant effect ($P < 0.05$) of gestation housing system for total number of piglets born per litter was that of Salak-Johnson et al. (2007) that showed a greater number with group housed females housed at a floor space of 3.3 m^2 /sow (14.2) compared to individual crates (11.1); however, sows housed in groups at a floor space of either 2.3 or 1.4 m^2 /sow had a similar number of piglets born alive (12.0 and 12.4, respectively) than those in individual crate treatment (11.1). Of note, in this study a large number of the sows on the study (152 out of the 217 sows) had been housed in individual crates prior to being allotted to the study (Salak-Johnson et al., 2007).

As previously described 10 out of 11 studies in Table 1a & 1b, showed no effect of gestation housing system on the number of piglets born alive per litter. There was one studies that reported that sows housed in individual crates had a greater number of piglets born alive compared to those housed in both small and large pens (12.6, 8.9, and 9.9, respectively; Broom et al., 1995).

The study of Broom et al. (1995) was the only one that found a difference ($P < 0.05$) in the number of piglets born mummified per litter, with sows in small pens having more (0.6) than either those housed in large pens or individual crates (0.1 and 0.0, respectively).

Only one out of 5 studies summarized showed an effect ($P < 0.05$) of sow housing system on the number of piglets weaned. Karlen et al. (2007) reported a greater ($P < 0.05$) number of piglets weaned per litter in group housed sows (9.0) compared to those housed in individual crates (8.3).

Only one of the studies reported an effect of housing system ($P < 0.05$) on litter weaning weight. This study was conducted by Salak-Johnson et al. (2007) and found that the greatest litter weaning weight was for sows housed in individual crates (52.4 kg), while the sows housed in groups at the 2.3 m^2/ sow space allowance had the lowest (45.5 kg), and sows housed in groups at floor spaces of 1.4 and 3.3 m^2 had similar litter weaning weights (50.2 and 49.5 kg, respectively) to both the individual crate and 2.3 m^2 /sow space allowance treatment.

REPRODUCTIVE TRAITS AND REMOVAL RATE

A total of 5 studies were found that evaluated the effects of gestation housing system on sow reproductive traits (summarized in Table 2a & 2b). Two studies reported that sow removal rate was similar ($P > 0.05$) between housing treatments. Wean to insemination interval was reported in 4 studies with all of these showing no difference ($P > 0.05$) between housing treatments.

Three studies summarized in Table 2a & 2b reported a higher ($P < 0.05$) farrowing rate for sows in individual crates compared to those housed in groups (Johnston et al., 2013; Karen et al., 2007; Knox et al., 2014). Johnston et al. (2013) reported that sows housed in individual crates had a higher farrowing rate (97.6), than those housed in pens of 6 or 26 sows (94.8 and 92.2, respectively). Similarly, Karlen et al. (2007) reported that farrowing rate was higher for sows housed in individual crates (76.9%) compared to those housed in a hoop structure in groups of 85 sows (66.0%). Knox et al. (2014) compared the performance of sows housed in either individual crates or in groups in pens with ESF that were mixed on either day 3, 14, or 35 post insemination. The greatest farrowing rates were for animals housed in individual crates (92.8%) and for group housed sows mixed at day 35 (90.5%), whereas group housed sows mixed at day 3 had a lower farrowing rate than these two treatments (82.8%); the group-housed sows mixed at day 14 had a farrowing rate that was intermediate to and not statistically different from the other treatments (87.8%). However, Jansen et al. (2007) showed no difference in farrowing rate between sows housed in either individual crates (77.8%) or groups of 50 sows (76.6%).

Two of the studies summarized in Table 2a & 2b evaluated the effect of gestation housing system on sow removal rates with both of these reporting no difference ($P > 0.05$) between individual and group housing (Karlen et al., 2007; Li et al., 2014). However, Li et al. (2014) showed that sow removal rate after 3 reproductive cycles was significantly higher ($P < 0.05$) for sows housed in groups using ESF compared to those housed in individual crates.

SOW BODY CONDITION SCORE & SOW BODY WEIGHT

In group housing there are several ways to administer feed to sows that might affect the animal's weight or gain during gestation. Three studies were found that administered feed once per day through an electronic sow feeder (Broom et al., 1995; Knox et al., 2014; Li et al., 2014).

Six additional studies fed animals once per day during gestation (DeDecker et al., 2014; Harris et al., 2006; Karlen et al., 2007; Munsterhjelm et al., 2008; Salak-Johnson et al., 2007; Zhao et al., 2013). However, two studies fed animals twice per day during gestation (Jansen et al., 2007; Johnston et al., 2013). Also in group housing the amount of feed given to animals per day also might affect the animal's weight or gain during gestation. Two studies fed 2.2 kg/sow/day (Broom et al., 1995; Zhao et al., 2013) and two studies fed 2.5 kg/sow/day (Karlen et al., 2007; Salak-Johnson et al., 2007).

One study summarized in Table 3 evaluated the impact of gestation housing system on body condition score (BCS) (Salak-Johnson et al., 2007) and reported that sows housed in individual crates had a higher score ($P < 0.05$), indicating a greater body fat level, compared to those housed in groups.

Four out of the 11 studies that are summarized in Table 3 reported on sow body weights. There were two studies that reported no difference ($P > 0.05$) between gestation housing systems. However, two studies showed a difference ($P < 0.05$) between housing systems for sow body weights at farrowing and at weaning. One study reported that sows housed in individual crates compared to groups had higher body weight (Johnston et al., 2013) and one study reported that group-housed sows weighed more (Salak-Johnson et al., 2007).

Two studies showed an effect ($P < 0.05$) of gestation housing system on sow body weight prior to farrowing (Johnston et al., 2013; Salak-Johnson et al., 2007). Johnston et al. (2013) reported that sows housed in both small and large groups were lighter at farrowing than those in individual crates. However, Salak-Johnson et al. (2007) found that group housed sows kept at floor spaces of 3.3 and 2.3 m^2 were heavier at farrowing than sows housed in individual crates or in groups at a floor space of 1.4 m^2.

Two of the studies reported a difference (P < 0.05) for sow body weight at weaning (Johnston et al., 2013; Salak-Johnson et al., 2007). One study reported that sows housed in individual crates during gestation were heavier (P < 0.05) at weaning than those housed in groups (Johnston et al., 2013). In contrast, Salak-Johnson et al. (2007) reported that sows housed in groups at a floor space of 2.3 m^2 were heavier (P < 0.05) than those in individual crates.

Body weight changes from allotment to farrowing and from farrowing to weaning were reported in two of the studies summarized in Table 3. One study reporting no difference (P > 0.05) between the housing treatments (Salak-Johnson et al., 2007) and the other reporting a greater (P < 0.05) body weight change in sows housed in individual crates compared to groups (Johnston et al., 2013). Body weight change from allotment to farrowing was reported in the study of Johnston et al. (2013) as being greater (P < 0.05) for sows housed in individual crates (41.5 kg) compared to those housed in large groups (33.4 kg). Johnston et al. (2013) also reported a difference (P < 0.05) between housing systems for the change in sow body weight from farrowing to weaning. In this study, sows housed in individual crates had the greatest body weight loss (37.0 kg) with sows housed in the large group pens of 26 having the lowest body weight loss (32.0 kg), and sows housed in the small pens having similar body weight loss to the other two treatments (34.1 kg).

CONCLUSION

This literature review has summarized studies that have compared the effect of individual and group housing systems for sows during gestation on sow performance. In general, the results of these studies for sow litter performance have been variable with some showing an advantage for group housing with others showing the opposite and some finding no difference between the two gestation housing systems. However, most studies evaluating the effect of gestation housing system on farrowing rate found that this tended to be lower for groups compared to individual crates (Johnston et al., 2013; Karlen et al., 2007; Knox et al., 2014). This negative effect of group housing on farrowing rates may in part be due to the timing of group formation. Knox et al. (2014) found that conception rate was lower when sows were mixed at day 3 compared to day 35 of gestation. The results of studies evaluating body weight are also variable and only one study has been conducted evaluating body condition score. Sow gestation housing system research is a relatively new area in the US and only a few studies have been conducted comparing group and individual housing systems. In addition, there were no studies found in the scientific literature that evaluated the offspring of group housed females. Furthermore, the potential for legislation to ban the use of gestation crates during parts of the production process highlights the need to for further research in this area.

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TABLES

Table 1a. Summary of studies evaluating effect of sow housing systems on sow litter performance.

Study	Total # of sows on study	Housing systems compared	Treatment	# of sows /pen	Floor space, m^2 /sow	Day of gestation when mixed	# of piglets born alive	# of piglets born dead	# of piglets born mummified	Total # of piglets born	# of piglets weaned	Piglet pre-weaning mortality, %	Litter birth wt, kg.	Litter weaning wt, kg.
Broom et al., 1995	65	Small and large ESF pens or Individual crates	Crate	-	-	-	12.6^{a}	-	0.0^{b}	-	-	-	-	-
			Small pen	5	1.3	49	8.9^{b}	-	0.6^{a}	-	-	-	-	-
			Large pen	38	1.65	49	9.9^{b}	-	0.1^{b}	-	-	-	-	-
			Significant	-	-	-	yes	-	yes	-	-	-	-	-
DeDecker et al., 2014[1]	221	Group pens or Individual crates	Crate	-	-	-	-	-	-	-	-	-	-	-
			1.7 m^2	10	1.7	35	-	-	-	-	-	-	-	-
			2.3 m^2	10	2.3	35	-	-	-	-	-	-	-	-
			Significant	-	-	-	no	no	no	no	no	-	-	-
Harris et al., 2006	22	Group pens or Individual crates	Crate	-	1.3	-	8.9	-	-	9.6	-	18.1	16.8	-
			Mixing d7	4	2.4	7	7.8	-	-	9	-	13.4	15.2	-
			Significant	-	-	-	no	-	-	no	-	no	no	-
Li et al., 2014[2]	401	ESF pens or Individual crates	Crate	-	1.3	-	11.6	0.5	-	12.2	10.1	9.3	17.5	64.6
			ESF pen	50	2.2	7	10.8	0.6	-	11.4	10	8.1	16.9	64.3
			Significant	-	-	-	no	no	-	no	no	no	no	no
Jansen et al., 2007[3]	96	Group pens or Individual crates	Crate	-	-	-	10.5	-	-	-	-	-	-	-
			Pen	50	2.1	65-70	9.7	-	-	-	-	-	-	-
			Significant	-	-	-	no	-	-	-	-	-	-	-
Johnston et al., 2013[4]	815	Group pens or Individual crates	Crate	-	1.2	-	12.3	0.9	0.3	13.1	10.3	-	-	72.3
			Group	6	1.5	35	12.2	0.9	0.3	13.1	10.1	-	-	71.3
			Group	26	1.5	35	12.5	0.7	0.4	13.2	10.2	-	-	71.7
			Significant	-	-	-	no	no	no	no	no	-	-	no
Karlen et al., 2007	640	Group pens or Individual crates	Crate	-	-	-	10.1	0.7	0.3	11.2	8.3^{b}	-	16.3	72
			Hoop pen	85	2.3	35	10.2	0.6	0.3	11.1	9.0^{a}	-	16.1	71.3
			Significant	-	-	-	no	no	no	no	yes	-	no	no

Table 1b. Summary of studies evaluating the effect of sow housing systems on sow litter performance (continued).

Study	Total # of sows on study	Housing systems compared	Treatment	# of sows /pen	Floor space, m^2 /sow	Day of gestation when mixed	# of piglets born alive	# of piglets born dead	# of piglets born mummified	Total # of piglets born	# of piglets weaned	Piglet pre-weaning mortality, %	Litter birth wt, kg.	Litter wean wt, kg.
Knox et al., 2014[5]	1436	ESF pens or Individual crates	Crate	-	1.3	-	11.8	0.6	0.1	12.4	-	-	-	-
			Mixing d3	58	1.7	3	11.3	0.5	0.1	11.9	-	-	-	-
			Mixing d14	58	1.7	14	11.6	0.7	0.1	12.4	-	-	-	-
			Mixing d35	58	1.7	35	11.5	0.6	0.0	12.2	-	-	-	-
			Significant	-	-	-	no	no	no	no	-	-	-	-
Munsterhjelm et al., 2008	275	Group pens or Individual crates	Crate	-	-	-	11.7	1.2	-	-	-	-	-	-
			Pen	8	5.1	28	12.1	1.0	-	-	-	-	-	-
			Significant	-	-	-	no	no	-	-	-	-	-	-
Salak-Johnson et al., 2007	217	Group pens or Individual crates	Crate	-	1.3	-	9.4	-	-	11.1[b]	8.7	-	15.0	52.4[a]
			1.4 m^2	5	1.4	28	10.0	-	-	12.4[b]	8.6	-	15.7	50.2[ab]
			2.3 m^2	5	2.3	28	9.5	-	-	12.0[b]	8.1	-	15.2	45.5[b]
			3.3 m^2	5	3.3	28	10.5	-	-	14.2[a]	8.8	-	16.6	49.5[ab]
			Significant	-	-	-	no	-	-	yes	no	-	no	yes
Zhao et al., 2013[6]	48	Group pens or Individual crates	Crate	-	-	-	11.1	1.9[ab]	0.5	13.4	-	-	16.8[a]	50.0[ab]
			High rank	3	2.5	35	9.6	2.6[a]	0.5	12.6	-	-	13.6[b]	43.1[b]
			Medium rank		2.5	35	10.3	1.2[b]	0.3	11.8	-	-	16.3[a]	47.8[ab]
			Low rank		2.5	35	11.2	1.4[b]	0.3	12.8	-	-	16.6[a]	51.8[a]
			Significant	-	-	-	no	no	no	no	-	-	no	no

[a,b]Within each study, means within a column with different superscripts differ ($P \leq 0.05$).

[1]Litter performance values were not reported; no statistical differences

[2]Data used was from 1 reproductive cycle; dynamic grouping, mixed at 8 week intervals; after 3 reproductive cycles removal rate was significantly higher for the group housed treatment.

[3]Data recorded for the sows housed in pens, used 18 out of 50 in each pen to compare to the 18 sows housed in stalls.

[4]Average parity: crates 3.8, small pen 3.1, large pen 3.9.

[5]Sow weaning to estrus interval was recorded not wean to mating interval.

[6]Pen of 3 separated into Social rank treatments (high, medium and low) significance was for the evaluation between individual crates compared to group pen.

Table 2a. Summary of studies evaluating the effect of sow housing systems on sow reproductive traits.

Study	Total # of sows on study	Housing systems compared	Treatment	# of sows /pen	Floor space, m^2 /sow	Day of gestation when mixed	Sow farrowing rate, %[1]	Sow removal rate, %[3]	Sow weaning to insemination interval, d[4]
Li et al., 2014[6]	401	ESF pens or Individual crates	Crate	-	1.3	-	-	13.6	-
			ESF dynamic	50	2.2	7	-	19.4	-
			Significant	-	-	-	-	no	-
Jansen et al., 2007[7]	96	Group pens or Individual crates	Crate	-	-	-	77.8	-	10.2
			Pen	50	2.1	65-70	76.6	-	10.5
			Significant	-	-	-	no	-	no
Johnston et al., 2013[8]	815	Group pens or Individual crates	Crate n=326	-	1.2	-	97.6	-	5.2
			Group n=154	6	1.5	35	94.8	-	5.4
			Group n=335	26	1.5	35	92.2	-	5.6
			Significant	-	-	-	yes	-	no
Karlen et al., 2007	640	Group pens or Individual crates	Crate	-	-	-	76.9[a]	2.8	-
			Hoop pen	85	2.3	35	66.0[b]	1.7	-
			Significant	-	-	-	yes	no	-

Table 2b. Summary of studies evaluating the effect of sow housing systems on sow reproductive traits (continued).

Study	Total # of sows on study	Housing systems compared	Treatment	# of sows /pen	Floor space, m^2 /sow	Day of gestation when mixed	Sow farrowing rate, %[1]	Sow removal rate, %[3]	Sow weaning to insemination interval, d[4]
Knox et al., 2014[9]	1436	ESF pens or Individual crates	Crate	-	1.3	-	92.8[a]	-	4.5
			Mixing d3	58	1.7	3	82.8[b]	-	4.3
			Mixing d14	58	1.7	14	87.8[ab]	-	4.2
			Mixing d35	58	1.7	35	90.5[a]	-	4.4
			Significant	-	-	-	yes	-	no
Munsterhjelm et al., 2008	275	Group pens or Individual crates	Crate	-	-	-	-	-	5.1
			Pen	8	5.1	28	-	-	5.3
			Significant	-	-	-	-	-	no
Zhao et al., 2013[10]	48	Group pens or Individual crates	Crate	-	-	-	87.5[ab]	-	-
			High rank	3	2.5	35	91.7[ab]	-	-
			Medium rank		2.5	35	95.7[a]	-	-
			Low rank		2.5	35	72.0[b]	-	-
			Significant	-	-	-	-	-	-

[a,b]Within each study, means within a column with different superscripts differ ($P \leq 0.05$).
[1]Sow farrowing rate was calculated as the percentage of sows assigned to treatment that were inseminated and farrowed a litter.
[2]Sow weaning rate was calculated as the percentage of sows assigned to treatment that were breed and weaned a litter
[3]Sow removal rate was calculated as the percentage of sows that were assigned to treatment that were culled, euthanized, or died while on study.
[4]Sow weaning to insemination interval was calculated as the number of days from weaning to insemination.
[5]Litter performance values were not reported; no statistical differences
[6]Data used was from 1 reproductive cycle; dynamic grouping, mixed at 8 week intervals; after 3 reproductive cycles removal rate was significantly higher for the group housed treatment.
[7]Data recorded in pens was using 18 out of 50.
[8]Average parity: crates 3.8, small pen 3.1, large pen 3.9.
[9]Sows bred within 10 d post weaning was recorded.
[10]Pen of 3 separated into Social rank treatments (high, medium and low) significance was for the evaluation between individual crates compared to group pen.

Table 3. Summary of studies evaluating effect of sow housing systems on sow body weight and body condition score.

Study	Total # of sows on study	Housing systems compared	Treatment	# of sows/pen	Floor space, m^2 /sow	Day of gestation when mixed	Sow weight at allotment, kg	Sow weight at farrowing, kg	Sow weight at weaning, kg	Sow body weight change, allotment to farrowing	Sow body weight change, farrowing to weaning	BCS[1]
Li et al., 2014[2]	401	ESF pens or Individual crates	Crate	-	1.3	-	-	206.0	199.0	-	-8.5	-
			ESF	50	2.2	7	-	204.0	199.0	-	-5.8	-
			Significant	-	-	-	-	no	no	-	no	-
Johnston et al., 2013[3]	815	Group pens or Individual crates	Crate	-	1.2	-	225.0^{a}	266.1^{a}	229.3^{a}	$+41.5^{a}$	-37.0^{a}	-
			Group n=154	6	1.5	35	217.4^{b}	256.6^{b}	224.5^{b}	$+39.5^{a}$	-34.1^{ab}	-
			Group n=335	26	1.5	35	222.6^{ab}	255.7^{b}	221.7^{ab}	$+33.4^{b}$	-32.0^{b}	-
			Significant	-	-	-	yes	yes	yes	yes	yes	-
Salak-Johnson et al., 2007[4]	217	Group pens or Individual crates	Crate	-	1.3	-	208.0	233.0^{b}	226.0^{b}	+25.0	-	3.76^{a}
			1.4 m^2	5	1.4	28	209.0	238.0^{b}	226.0^{b}	+31.5	-	3.17^{c}
			2.3 m^2	5	2.3	28	210.0	245.0^{a}	238.0^{a}	+34.2	-	3.48^{b}
			3.3 m^2	5	3.3	28	214.0	252.0^{a}	234.0^{ab}	+36.9	-	3.41^{b}
			Significant	-	-	-	no	yes	yes	no	-	yes
Zhao et al., 2013[5]	48	Group pens or Individual crates	Crate	-	-	-	240.5^{b}	282.1^{a}	272.0^{a}	-	-	-
			High rank	3	2.5	35	256.3^{a}	289.1^{a}	283.2^{a}	-	-	-
			Medium rank		2.5	35	237.6^{b}	260.4^{b}	256.2^{b}	-	-	-
			Low rank		2.5	35	233.8^{b}	262.9^{b}	258.2^{b}	-	-	-
			Significant	-	-	-	no	no	no	-	-	-

[a,b]Within each study, means within a column with different superscripts differ ($P \leq 0.05$).

[1]Body condition score (BCS) was based on a 1 to 5 scale; 1 being thin, 5 being fat, and 3 being ideal.

[2]Data used was from 1 reproductive cycle; dynamic grouping, mixed at 8 week intervals; after 3 reproductive cycles removal rate was significantly higher for the group housed treatment; sow weight at farrowing was after parturition.

[3]Average parity: crates 3.8, small pen 3.1, large pen 3.9.

[4]BCS was for phase 2; BCS evaluations once a week while in gestation and once at the end of lactation.

[5]Pen of 3 separated into Social rank treatments (high, medium and low) significance was for the evaluation between individual crates compared to group pen.

SECTION 2: FARROWING PEN SIZE AND DESIGN

INTRODUCTION

The type of accommodations where sows raise piglets has changed over time, with the producer's goal to decrease piglet mortality. In the late 1980's studies was conducted evaluating litter performance of sows housed in pens with and without farrowing crates. In the last 25 years there has been substantial improvements in genetics and management that have helped to increase the number of piglets born per litter. It can be estimated that litter size at birth has increased by between of 2 to 3 piglets over the last 25 years. Despite this increase, farrowing pen size (sow crate plus piglet area) in commercial facilities has not generally changed. In addition, there has been limited, if any published research studies investigating the effect of the increase in farrowing pen size for the piglets on pre-weaning mortality.

The following literature review summarizes previous research evaluating the effect of the design of farrowing pens on sow litter performance.

SOW LITTER PERFORMANCE

A total of 5 studies were found that evaluated the effects of sow farrowing pen design (farrowing crate compared to pens without crates) on sow litter performance and these are summarized in Table 4. Most of these studies showed no difference ($P > 0.05$) between the farrowing pen designs compared. Four out of 5 studies reported no significant effect for number born alive (Collins et al., 1987; Curtis et al., 1989; McGlone et al., 1990; and Gu et al., 2011). Three studies reported that number of piglets born dead was not different ($P > 0.05$) between treatments (Collins et al., 1987; Curtis et al., 1989; and McGlone et al., 1990). Two out of four studies reported no difference ($P > 0.05$) in the number of piglets weaned per litter (Collins et al., 1987; and Curtis et al., 1987). One out of 2 studies reported no significant effect ($P > 0.05$) for pre-weaning mortality (Collins et al., 1987). Litter weight was recorded in one study and showed no difference ($P > 0.05$) between treatments (McGlone et al., 1990).

Only one study reported a difference ($P < 0.05$) between treatments for the number of piglets born alive. In this study, Pedersen et al. (2011) reported that the median number of piglets born alive for farrowing crates was lower (13) than pens without crates (14). However, when looking at the number of piglets weaned per litter, Pedersen et al. (2011) reported that farrowing crates weaned more piglets (13) than the pens without crates. Another study showed a difference ($P < 0.05$) in the number of piglets weaned per litter (McGlone et al., 1990) and this, reported that the highest number of piglets weaned per litter was for the sloped floor pens without crates (8.4) and the lowest for level floor pens without crates (6.6) with pens with crates that had either level or sloped floors being intermediate for number weaned (8.2 and 7.6, respectively). This was also reflected in the piglet mortality with the highest levels being in level floor pens without crates and the lowest in the sloped floor pens without crates (McGlone et al., 1990). Gu et al. (2011) reported a difference ($P < 0.05$) in piglets crushed as a percentage of the total piglet pre-weaning mortality, with the highest percentage in farrowing pens without crates (25.5%) when compared to freedom pens without crates and farrowing crates (9.3% and 10.8%, respectively). Dyck et al. (1987) reported causes of piglet death in 8 categories for farrowing pens with crates; the top 3 reasons for piglet death were starvation, crushing, and stillborn (26.9%, 23.9%, and 22.3% of total deaths, respectively). Also in the study conducted by Dyck et al. (1987), 70.1% of the total deaths were from birth (including stillborn) through to the fourth day after birth.

CONCLUSION

Based on the literature review presented in this section the results suggested that sows farrowing in pens without crates can have an increased piglet mortality due to crushing, which is the reason why most commercial operations still use farrowing crates. Piglet crushing was the major causes of piglet death irrespective of pen design and increasing the pen size could lower the number of deaths. Furthermore, there has been an increase in the number of piglets born alive per litter over time which would suggest that farrowing pen size should be increased to accommodate the greater number of piglets. However, there are no reports in the scientific literature on the impact of farrowing pen size on piglet mortality; therefore, research is needed to address this issue.

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TABLES

Table 4. Summary of studies evaluating the effect of farrowing pen or crate design on litter performance.

Study	Total # of sows on study	Treatments	# of piglets born alive	# of piglets born dead	# of piglets weaned	Piglet mortality (pre-weaning), %	Piglets crushed (% of total pre-weaning mortality)	Litter weaning wt., kg
Collins et al., 1987[1]	118	Farrowing crate	10.0	0.5	8.7	12.0	-	-
		Sloped floor pen	10.5	0.4	8.9	12.4	-	-
		Significant	no	no	no	no	-	-
Curtis et al., 1989[2]	111	Fingered	9.4	0.4	8.4	-	-	6.4[a]
		Bowed	9.5	0.2	8.2	-	-	6.1[ab]
		Straight bar 20 cm	9.7	0.5	8.2	-	-	6.0[b]
		Straight bar 25 cm	9.5	0.4	8.5	-	-	6.3[a]
		Significant	no	no	no	-	-	yes
Gu et al., 2011[1]	18	Farrowing crate	11.2	-	-	-	10.8[b]	-
		Freedom pen	10.6	-	-	-	9.3[b]	-
		Farrowing pen	10.5	-	-	-	25.5[a]	-
		Significant	no	-	-	-	yes	-
McGlone et al., 1990[1]	40	Level floor crate	8.3	1.1	8.2	10.8	-	32.5
		Level floor pen	9.1	0.6	6.6	27.1	-	24.3
		Sloped floor crate	10.4	0.5	7.6	17.2	-	36.2
		Sloped floor crate	9.6	1	8.4	9.1	-	36.3
		Significant	no	no	no	no	-	no
Pedersen et al., 2011[1,3]	42	Farrowing crate	13	-	13	-	-	6.3
		Farrowing pen	14	-	12	-	-	7.1
		Significant	yes	-	yes	-	-	no

[a,b]Within each study, means within a column with different superscripts differ ($P \leq 0.05$).
[1]Evaluated sows housed in crates versus pen during lactation.
[2]Farrowing crate design was evaluated; 4 farrowing crate bottom bar designs.
[3]Number after fostering was used not born alive; and the median was used for all variables.

CHAPTER 2: THE IMPACT OF GESTATION SOW HOUSING SYSTEM (INDIVIDUAL VS. GROUP) ON THE REPRODUCTIVE PERFORMANCE OF SOWS

INTRODUCTION

It has been a common practice on most commercial facilities to keep females in individual crates during gestation but there has been recent pressure to change to keeping gestating females in group pens. The objective of the proposed study was to compare group housing with individual housing during gestation. One of the low cost ways to convert existing gestation crate facilities to pens is by taking the back section out from two rows of crates and installing gates to create pens. Although there has been some published research comparing the two gestation housing systems, there is a need to validate and improve the way (i.e. pen design, feeding method, water access, and group size) group housed sows are kept to maintain the productivity of the animals.

Therefore, the objective of this study was to compare the reproductive performance of females housed in individual gestation crates or in groups during gestation.

MATERIALS AND METHODS

The two studies reported in this thesis were conducted at South Ridge Sow Farm, a breed-to-wean facility located near Pittsfield, IL, owned and operated by The Maschhoffs LLC (Carlyle, IL). The experimental protocol was approved by the University of Illinois Institutional Animal Care and Use Committee.

Background

The South Ridge Sow Farm was repopulated in August 2014 with gilts (parity 0) that were bred at an offsite facility (Honeycreek Farm). Initially at Honeycreek Farm, gilts were kept in pens of approximately 100. They were checked for estrus by farm personnel using fence line presence of a boar and the back pressure test. Once estrus was observed, females were artificially inseminated once every 24 hours until estrus was not observed. After breeding, gilts were moved into a pen of approximately 80 animals. They were checked for returns to estrus, and rebred if they returned, and were pregnancy checked between day 28 and 35 of gestation (using an EZ ultra-sound machine). Gilts between day 21 and 107 of gestation were transported to South Ridge sow farm over a 4 week period with sows closest to farrowing moved first. All animals had ad-libitum access to feed and water throughout the duration of time at the offsite facility.

Experimental Design and Treatments

This study was carried out as a Randomized Complete Block Design; the blocking factor was breeding group (females bred within 7 days). Two housing systems for gestating sows were compared: 1). Individual Housing, 2). Group Housing. This study was designed to monitor the performance of the females through to weaning from the fifth parity. The results presented in this thesis relate to performance of females in parity 0 and 1. Parity 0 was defined as animals between insemination and weaning of first litter. The study began when gilts of parity 0 were allotted to treatment. Those that arrived at South Ridge between day 35 and 85 of gestation were allotted to treatment on arrival. Females delivered at less than day 35 of gestation were housed in stalls until at day 35 of gestation at which time they were allotted to treatment. Females that were greater than day 85 of gestation were not assigned to treatment as parity 0 animals but were allotted to treatment as parity 1 sows at day 35 of the following gestation.

Animals and Allotment to Study

A total of 1325 crossbred females from 14 genetic lines (mainly of Landrace and Yorkshire origin) were used in this study. Only females that had been confirmed pregnant and did not have injuries that might prevent them from completing five parities were allotted. Allotments were carried out on day 35 of gestation (with the exception of females that were between day 36 and 84 of gestation on arrival at South Ridge that were allotted to treatment on arrival) within genetic line and breeding group. Females were formed into outcome groups of 2 of the same parity, genotype, and similar body condition and were randomly allotted from within outcome group to either the Individual or Group Housing treatment. This process was repeated until all of the females in the breeding group were allotted to the study. If following the allotment, there was an incomplete replicate of females (i.e., less than 16) then females from the next breeding group were used to complete the replicate. After females were allotted to treatment at day 35 of gestation they were moved from the breeding area of the barn to the gestation area within the barn. The females allotted to the Group Housing treatment were moved to their designated pens; the females allotted to the Individual Housing treatment were moved to individual crates located in the same area of the gestation barn as close as possible to the Group Housed females from the same replicate. The gestation barn layout is presented in Figure 1.

Animal Housing

The gestation facility consisted of two housing types, crates and pens. Crate dimensions were 0.54 m x 2.07 m, giving a floor area of 1.12 m² per female. Pens dimensions were 2.20 m x 4.71 m, giving a floor area of 1.30 m² per female. A schematic of the Group housing treatment is presented in Figure 3. From weaning of sows or arrival of gilts onto the unit until they were moved to the gestation housing systems, all females were housed in crates that were equipped with a drop type feeder that emptied into a trough and a nipple-type water drinker that was located between two crates. The pens and crates that were used for the gestation housing system comparison were equipped with a drop type feeder that emptied into a water trough, which had water in it continuously, thus, creating a wet-dry feed mixture. Temperature in the gestation barn was maintained using a thermostat and fan ventilation and evaporative cooling cells that were used in warm weather. Temperature and humidity were measured using three EL-USB-2 data logger units located in the center of the facility and placed equidistant along the length of the building. The average temperature and humidity during the study period were 21.2° C and 65.3%, respectively, with a range from 8.3° C to 28.3° C, and 32% to 99%, respectively.

The farrowing facility consisted of 9 rooms with either 24 or 26 farrowing pens per room. Farrowing crates, which were located within each farrowing pen, were 0.55 m wide and either 1.95 m (rooms 1-7) or 2.19 m (rooms 8 and 9) long, giving a total floor area per sow within crate a 1.07 m^2 or 1.20 m^2, respectively. Crates were equipped with a cup type drinker and a trickle type feeder that dropped feed into a feed trough. The thermostat in the room was set at 22.5° C until all sows had farrowed then decreased by 0.25° C per day for 10 days until it reached 20.0° C, then decreased over the next 5 days to 19° C where the thermostat setting remained until weaning.

Breeding and Gestation Management

Mating's were carried out as previously described in the Background section with the exception that once mating's started at South Ridge Sow Farm these were carried out in individual crates.

Water troughs were checked daily to ensure all animals had access to water. Every animal was visually evaluated for health issues at the time of feeding (e.g. off feed, lameness, injury, fever, respiratory conditions, etc.). Any animal that was not standing at the time of evaluation was assisted to stand and evaluated. Any animal that was removed from a pen after day 35 of gestation was placed in a non-study crate and monitored until that animal was moved into the farrowing facility at approximately day 112 of gestation. Criteria for animal removal from a pen included females that were 0.5 of a body condition score below the average of the pen, animals that were not responsive to the first round of treatment for any condition, or had injuries that warranted immediate removal.

Farrowing Management

At approximately day 112 of gestation females were moved into the farrowing facility and were assigned to crate by the date that they were due to farrow. Management in the farrowing facility was generally in accordance with standard unit procedures. In the early period of the study (i.e., first 6.5 months), cross-fostering was only carried out between sows on the same sow housing treatment. However, due to practical problems with this approach, from April 5, 2015 onwards the protocol was changed to allow cross-fostering between sows on both treatments. Sows were weaned at 22 ± 2.2 days.

Diet Formulation and Feeding

Diets were formulated to meet or exceed the nutrient requirements for breeding, gestation and lactating pigs, proposed by the NRC (2012). In breeding and gestation, animals were fed twice daily at approximately 6:00 h and 11:00 h. The amount of feed given to gilts was based on body weight at breeding (Table 9) and the amount given to sows was based on body condition score (Table 10) which was evaluated on days 7, 35, 60, and 90 of gestation. Females in group pens were fed according to the average body condition score of all of the females in the pen; those on the individual crate treatment were fed according to individual body condition score. In farrowing, females were fed twice daily until parturition after which they were given ad libitum access to feed until weaning.

Body Condition Score and Body Weight Measurements

All females were evaluated for body condition at approximately day 35, 60, and 90 of gestation, and at farrowing, weaning, and day 7 after re-breeding. The body condition score scale used was from 2.5 to 3.5 in 0.25 increment between scores (Figure 2); a score of 2.5 was considered thin and of 3.5 fat. Body weights were recorded on a subsample of animals which consisted of females from four breeding groups (223 females in total). Weights were recorded on day 35 of gestation, on entry into farrowing, and at weaning.

Farrowing Measurements

The date of farrowing was recorded, as well as if the sow was induced to farrow. Sows not farrowing by day 114 of gestation were induced by injecting 1 mL of Lutalyse® (Pfizer Animal Health US) at both 6:00 h and 12:00 h.

The number of piglets born alive, born dead, and mummified were recorded and used to calculate total number of piglets born. After farrowing was complete, all piglets born alive and dead were weighed together to obtain a litter birth weight. Litters were weighed again at weaning to obtain a litter weaning weight. The date and cause of piglet deaths was recorded from birth until weaning. The date of weaning was also recorded.

Breeding and Sow Records Measurements

The date of insemination was recorded and the weaning to insemination interval was calculated. In addition, days from weaning to rebreeding was recorded for animals that returned to estrus following the first mating. The date and reason for death or removal were also recorded.

Statistical Analysis

Normality and homogeneity of variance was tested using the PROC UNIVARIATE procedure of SAS (SAS Inst. Inc., NC). Data that were normally distributed were analyzed using the PROC MIXED procedures of SAS (Littell et al., 1996). The experimental unit was individual female for all measures and the model accounted for the fixed effects of treatment and parity and random effect of replicate. Data that was not normally distributed were transformed using the

PROC RANK procedures of SAS. Binary response data were analyzed using the PROC FREQ procedures of SAS using the chi-square test to evaluate differences between treatment means. Least-square means were separated by using the PDIFF option of SAS with treatment means being different at $P \leq 0.05$.

RESULTS AND DISCUSSION

A total of 1325 females were allotted to Sow Gestation Housing treatments, resulting in 1695 individual litter recordings (847 and 848 for Individual and Group treatment, respectively). A number of sow records were removed prior to analysis and there were several reason for this including: sows having all piglets cross-fostered off (115 records), discrepancies between numbers recorded (number born alive, number after cross-fostering, or number weaned) (88 records), sow found not pregnant (28 records), sow used as a nurse sow after weaning first litter (15 records), and data points that were determined to be outlier (± 3 standard deviations; 36 records).

Litter Performance

Gestation Housing Treatment by Parity Interactions

There was Gestation Housing treatment by Parity interaction ($P < 0.05$) for number of piglets per litter after cross-fostering and at weaning (Table 5). The number of piglets per litter after cross-fostering was similar for the two Gestation Housing treatments in Parity 1 but was greater for the Group than the Individual treatments in Parity 0. This interaction was unexpected and was most likely due to chance particularly as there was no treatment interaction for number born. The number of piglets weaned per litter was similar for the two Gestation Housing treatments in Parity 0 but was greater for the Individual than the Group treatment in Parity 1. The number of piglets per litter after cross-fostering, although not statistically significant, was numerically greater for the Individual treatment in Parity 1 (+0.2 piglets) and this would have contributed to the treatment difference in number weaned in favor of the Individual treatment in Parity 1 (+0.3 piglets).

Effects of Gestation Housing Treatment

There were no differences (P > 0.05) between Individual and Group treatments for number of piglets born (alive, dead, mummified, total), litter weights (birth, weaning) or piglet weights (birth, weaning) (Table 5). These results are in agreement with most studies that have compared group and individual gestation housing systems (presented in the literature Table 1a & 1b; DeDecker et al., 2014; Harris et al., 2006; Li et al., 2014; Jansen et al., 2007; Johnston et al., 2013; Karlen et al., 2007; Knox et al., 2014; Munsterhjelm et al., 2008; Salak-Johnson et al., 2007; Zhao et al., 2013). However, the current study is in disagreement with that of Broom et al. (1995) which reported that sows in group housed treatments had fewer piglets born alive in either small or large groups and more born mummified in small groups than those kept in individual crates. In addition, Salak-Johnson et al. (2007) found a greater total number of piglets born for sows housed in groups at a space allowance of 3.3 m^2/sow in groups, compared to those kept in either in individual crates, or in groups at a space allowance of either 1.4 or 2.3 m^2/sow.

In the current study, pre-weaning mortality was greater ($P \leq 0.05$) for the Group (9.3%) compared to the Individual treatment (8.2%). This result is in disagreement with two studies that reported (Table 1) no effect of group compared to individual housing of sows during gestation on pre-weaning mortality (Harris et al., 2006; and Li et al., 2014). The reason for the difference in pre-weaning mortality between housing systems found in the present study is not clear; the treatment difference was relatively small (1.1 percentage units) but would be commercially important. This finding requires validation in subsequent studies.

Effects of Parity

Parity 1 females had greater (P < 0.05) litter size at birth (alive and total), after cross-fostering, and weaned than Parity 0 females (Table 5). Total litter weight at birth and weaning was also greater for Parity 1 than Parity 0 which was to be expected given the greater number of piglets per litter for this treatment. In addition, piglet weaning weight was also greater for Parity 1 than Parity 0 which suggests that Parity 1 females produced more milk than Parity 0 females. Furthermore, pre-weaning mortality was also greater for Parity 1 than Parity 0 which probably reflects the greater number of piglets born to Parity 1 females.

Parity 1 females weaned heavier litters (P < 0.05) than Parity 0 animals (Table 5). This result was as expected as Parity 1 also had a greater number born alive and weaned

Reproductive Traits and Removal Rate

Gestation Housing Treatment by Parity Interactions

There were no treatment interactions (*P* > 0.05) for either weaning to insemination interval or weaning to re-breeding interval (Table 6). The treatment interactions could not be tested for the percentage of females induced to farrow, farrowing rate, and female removals as the data was analyzed using PROC FREQ procedure of SAS.

Effects of Gestation Housing Treatment

There was no difference (*P* > 0.05) between Gestation Housing treatments for the percentage of females induced to farrow, weaning to insemination interval, and weaning to re-breeding interval. The results for weaning to insemination interval is in agreement with all published studies that have compared group and individual gestation housing systems (presented in the literature Table 2a & 2b; Jansen et al., 2007; Johnston et al., 2013; Knox et al., 2014; Munsterhejelm et al., 2008). There were no studies found in the scientific literature that presented information on the effect of gestation housing system on the percentage of females induced to farrow, or weaning to re-breeding interval.

In the current study there was a difference ($P \leq 0.05$) between the Gestation Housing treatments for farrowing rate with the Individual treatment having a higher rate (96.6 %) than the Group treatment (92.7 %). It should be noted that farrowing rate refers to the number of females that were allotted to the study and actually farrowed a litter. These results are in agreement with 4 of the studies summarized in the literature review (Table 2a & 2b; Johnston et al., 2013; Karlen et al., 2007; and Knox et al., 2014; Zhao et al., 2013) which also showed higher farrowing rate for individually housed females. However, in the study conducted by Knox et al. (2014) the individually housed females had similar farrowing rates to those that were housed in groups that were formed by mixing females at day 14 and 35 of gestation; however, groups that were formed by mixing females at day 3 that had a lower farrowing rate than the individually housed animals. One study reported no difference between group and individual housed females (Jansen et al., 2007), however, in this study the groups were formed at between days 65 to 70 of gestation whereas in the current study the groups were formed at day 35 of gestation. These differences between studies in the timing of mixing of females to form the groups may have contributed to the different findings.

The Individual treatment had a lower ($P < 0.05$) removal rate (14.2 %) than the Group treatment (19.9 %) (Table 6). These results are in disagreement with two studies (Li et al., 2014; and Karlen et al., 2007) that compared group and individual housed systems and reported no difference between gestation housing treatments for the percentage of sows removed. In the study of Li et al. (2014) the removal rate was not different after 2 reproductive cycles, however, after 3 reproductive cycles the removal rate was greater for the group compared to the individually housed treatment.

Effects of Parity

Parity 0 females had a greater ($P \leq 0.05$) percentage of females induced to farrow, lower weaning to insemination interval, and lower removal rate compared to Parity 1 females (Table 6). It should be noted, that data collection ended at day 7 post insemination, and the removal rate for Parity 1 will not reflect the females that were culled for reproductive problems after this time.

Sow Body Condition Score and Body Weight

Gestation Housing Treatment by Parity Interactions

There were treatment interactions ($P < 0.05$) for body condition score (BCS) at day 7 post insemination and female body weight at weaning (Table 7). The BCS at day 7 post insemination and female body weight at weaning were similar for the two Gestation Housing treatments in Parity 0 but were greater for the Group than Individual treatments in Parity 1. However, the treatment differences were relatively small and could be due to Parity 1 females in the Individual treatment having a higher number weaned (11.5) than the Group treatment (11.2).

Effects of Gestation Housing Treatment

With the exception of the interaction described above, there were no differences ($P > 0.05$) between the gestation housing systems for BCS at any of the times of measurement (Table 7). These results are in disagreement to the one study that compared group and individual gestation housing system (Salak-Johnson et al., 2007), that reported an average BCS (gestation through weaning) that was highest for the individual treatment. In the study of Salak-Johnson et al., (2007) all females regardless of parity, BCS, or housing treatment were fed 2.5 kg per day and group housed females were fed on a solid floor. In the current study, the amount of feed was based on parity and BCS (Individual treatment based on individual BCS and parity of female; Group treatment based on average BCS and parity of pen) and feed was delivered in a trough, which might explain the difference in outcomes between the two studies.

Gestation feed consumption was calculated for Parity 1 females based on feed settings that were adjusted on BCS evaluations on days 7, 35, 60, and 90 of gestation. The average fed consumption was the same for both treatments, with an average consumption over the gestation period of 1.67 kg/sow/day.

With the exception of the Gestation Housing by Parity interaction described above, there was no effect ($P > 0.05$) of gestation housing system on sow body weight at any time during the reproductive cycle (Table 7). This finding is in disagreement with the results of the studies of Johnston et al. (2013) which suggested that body weights were generally higher for individually-housed sows, and Salak-Johnson et al. (2007) which found that body weight were generally lower for individually-housed compared to group-housed sows. In addition, Johnston et al. (2013) reported a difference between housing systems for female body weight gain from allotment to farrowing and from farrowing to weaning; in the current study there was no effect of housing treatment on sow body weight changes. However, Johnston et al. (2013) reported that female body weight gains were similar for the individual housed to the small group housed treatments but were lower for the larger group housed treatment. In the current study, the groups were of 8 sows and, therefore, the results were similar to those of Johnston et al. (2013) for small pens.

Effects of Parity

Parity 0 females had a higher BCS at allotment, and at day 60 and 90 of gestation than Parity 1 females. In addition, Parity 0 females were heavier at allotment, and farrowing, and lost more weight from farrowing to weaning than Parity 1 females. However, Parity 0 females had a lower BCS at weaning than Parity 1 females. These results were expected as Parity 0 females had never nursed a litter until farrowing and, consequently, had higher BCS and weight prior to and lower BCS and weight after farrowing than Parity 1 females.

Conclusion

In conclusion, most measures of sow reproductive performance did not differ between Gestation Housing treatments. However, females housed in groups had a lower farrowing rate and higher piglet pre-weaning mortality and removal rate than those housed in individual crates. As previously described the study is ongoing and will follow females through to the 5th parity and the additional data will help in understanding the effect of housing treatment on sow performance over time.

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TABLES

Table 5. Effect of Sow Gestation Housing treatment on litter performance.

	Housing treatment			Parity			*P*-value		
Item	Individual	Group	SEM	0	1	SEM	Housing Treatment	Parity	Treatment *Parity
Number of litter recordings	847	848		1031	664				
Number of piglets per litter:									
Born alive	12.0	12.1	0.13	11.5[b]	12.6[a]	0.13	0.44	<0.001	0.45
Born dead[1]	0.7	0.7	-	0.7	0.6	-	0.50	0.07	0.64
Born mummified[1]	0.2	0.2	-	0.2	0.2	-	0.35	0.58	0.55
Total born	12.8	12.9	0.14	12.3[b]	13.4[a]	0.15	0.50	<0.001	0.47
After cross-fostering	12.2	12.3	0.09	11.9[b]	12.6[a]	0.10	0.46	<0.001	0.01
Parity									
0	11.7[c]	12.1[b]							
1	12.7[a]	12.5[a]							
Weaned	11.2	11.1	0.08	10.9[b]	11.4[a]	0.08	0.40	<0.001	0.02
Parity									
0	10.8[c]	10.9[bc]							
1	11.5[a]	11.2[b]							
Pre-weaning mortality, %[2]	8.2[b]	9.3[a]	-	8.1[b]	9.7[a]	-	0.01	<0.001	-
Litter birth weight, kg[3]	19.2	19.3	0.22	18.5[b]	20.0[a]	0.24	0.69	<0.001	0.98
Piglet birth weight, kg[3]	1.5	1.5	0.02	1.5	1.5	0.02	0.99	0.06	0.32
Litter weaning weight, kg	74.7	73.4	0.92	70.6[b]	77.5[a]	1.08	0.09	<0.001	0.59
Piglet weaning weight, kg	6.7	6.6	0.07	6.5[b]	6.8[a]	0.08	0.53	<0.001	0.13

[a,b]Means within a row with different superscripts differ ($P \leq 0.05$).

[1]Data were analyzed using PROC RANK procedure of SAS.

[2]Data were analyzed using PROC FREQ procedure of SAS.

[3]Litter birth weight includes all piglets born alive and dead.

Table 6. Effect of Gestation Housing treatment on sow reproductive traits and removal rate.

	Housing treatment			Parity			*P*-value		
Item	Individual	Group	SEM	0	1	SEM	Housing Treatment	Parity	Treatment *Parity
Number of litter recordings	847	848		1031	664				
Induced to farrow, %[1]	94.4	94.0	-	92.9[b]	96.3[a]	-	0.68	0.005	-
Farrowing rate, %[1, 2]	96.6[a]	92.7[b]	-	94.9	94.3	-	<0.001	0.60	-
Weaning to insemination interval, d[3]	9.3	8.6	-	11.4[a]	5.5[b]	-	0.81	<0.001	0.85
Weaning to re-breeding interval, d[3]	56.5	48.9	-	55.9	44.3	-	0.25	0.09	0.26
Female removal rate, %[1]	14.2[b]	19.9[a]	-	22.1[a]	9.2[b]	-	0.002	<0.001	-

[a,b]Means within a row with different superscripts differ ($P \leq 0.05$).

[1]Data were analyzed using PROC FREQ procedure of SAS.

[2]Females allotted that farrowed a litter.

[3]Data were analyzed using PROC RANK procedure of SAS.

Table 7. Effect of Sow Gestation Housing treatment on sow body weight and body condition score.

	Housing treatment			Parity			*P*-value		
Item	Individual	Group	SEM	0	1	SEM	Housing Treatment	Parity	Treatment* Parity
Number of litter recordings	847	848		1031	664				
Body condition score									
Allotment[1]	3.45	3.45	-	3.47[a]	3.42[b]	-	0.14	<0.001	0.27
Day 60 of gestation[1]	3.46	3.46	-	3.47[a]	3.45[b]	-	0.15	<0.001	0.44
Day 90 of gestation[1]	3.47	3.47	-	3.48[a]	3.45[b]	-	0.18	<0.001	0.68
Farrowing[1]	3.42	3.42	-	3.42	3.42	-	0.29	0.91	0.78
Weaning[1]	3.27	3.27	-	3.25[b]	3.29[a]	-	0.70	0.04	0.07
Day 7 after breeding	3.39	3.40	-	3.40	3.39	-	0.19	0.14	0.03
Parity									
P0	3.40[a]	3.39[a]							
P1	3.37[b]	3.40[a]							
Female Body weight									
Allotment (day 35 of gestation)	179.5	180.5	2.17	186.4[a]	173.6[b]	2.42	0.64	<0.001	0.51
Farrowing	224.3	227.1	2.81	231.4[a]	220.0[b]	2.97	0.40	0.01	0.16
Weaning	185.2	188.9	2.38	188.4	185.7	2.44	0.22	0.46	0.03
Parity									
P0	189.9[a]	186.8[a]							
P1	180.5[b]	190.9[a]							
Body weight gain-allotment to farrowing, kg	+44.0	+46.2	1.84	+45.2	+45.0	1.75	0.40	0.95	0.45
Body weight gain-farrowing to weaning, kg	-38.3	-38.0	2.35	-43.5[a]	-32.7[b]	2.33	0.92	0.002	0.88

[a,b]Means within a row with different superscripts differ ($P \leq 0.05$).

[1]Data were analyzed using PROC RANK procedure of SAS.

Table 8. Sow Gestation Housing System mortality and removals.

	Housing treatment		
Item.	Individual	Group	*p*-value
Euthanized	**20**	**23**	
Percentage of total	**14.3**	**12.0**	**0.54**
Body condition score	1	3	
Farrowing difficulty	6	3	
Feet and legs	6	10	
Injury or trauma	2	5	
Unknown	2	0	
Prolapse	3	2	
Died	**16**	**30**	
Percentage of total	**11.8**	**15.1**	**0.39**
Body condition score	0	1	
Farrowing difficulty	6	8	
Feet and legs	0	1	
Injury or trauma	1	0	
Unknown	7	19	
Ulcer	0	1	
Prolapse	1	0	
Respiratory	1	0	
Removed[1]	**18**	**40**	
Percentage of total	**13.0**	**19.1**	**0.14**
Body condition score	0	5	
Feet and legs	0	2	
Injury or trauma	0	6	
Unknown	3	0	
Prolapse	0	1	
Abortion	5	1	
Found not pregnant	9	19	
Other[2]	1	6	
Culled	**66**	**76**	
Percentage of total	**35.5**	**31.0**	**0.33**
Body condition score	0	4	
Farrowing difficulty	0	1	
Feet and legs	2	5	
Injury or trauma	1	0	
Productivity	5	5	
No Estrus	43	43	
Not pregnant	9	18	
Return to Estrus	4	0	
Unknown	2	0	
Total	**120**	**169**	

[1]Removed was females that out of assigned treatment location between day 35 and 112 of gestation.

[2]Other removal reason was animals that did not experience the same conditions as there respected treatment.

Table 9. Feeding levels for gilts	
Gilt body weight at breeding (kg)	Total daily amount (kg/day)
118-127	4.54
128-136	4.10
137-145	3.64
146-155	3.64
156-164	3.18

Table 10. Feeding levels for sows (kg/day)					
	Body condition score (BCS)				
Parity	2.50	2.75	3.00	3.25	≥3.50
P 1-2	2.50	2.28	2.04	1.82	1.60
P ≥ 3	2.96	2.50	2.28	2.04	1.60

FIGURES

Figure 1. Layout of breeding and gestation facility at South Ridge illustrating the animal flow.

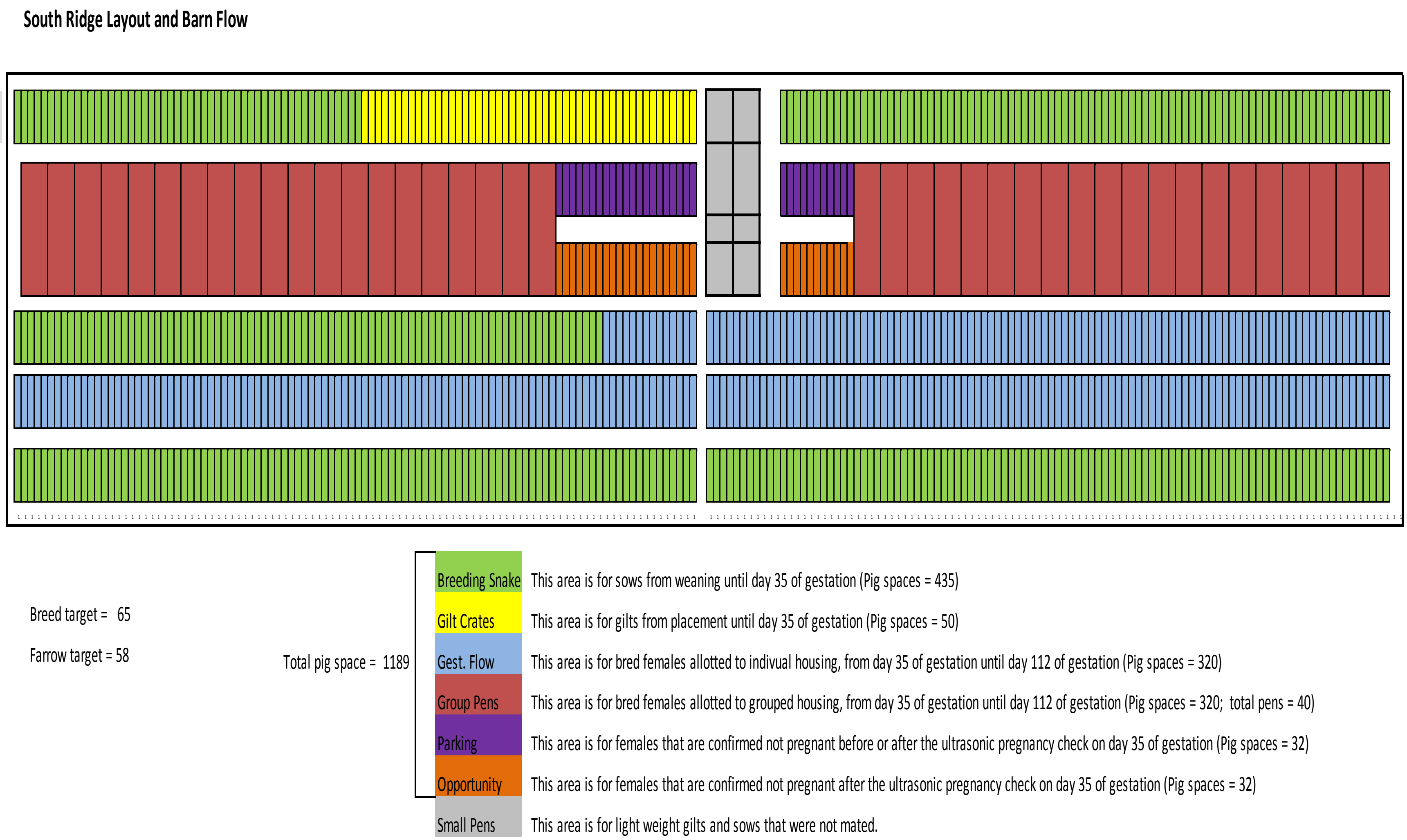


Figure 2. The Maschhoff body condition scoring.

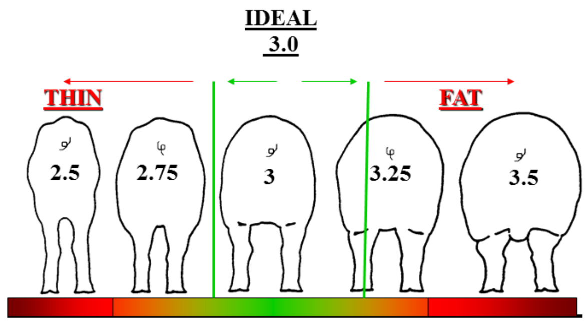
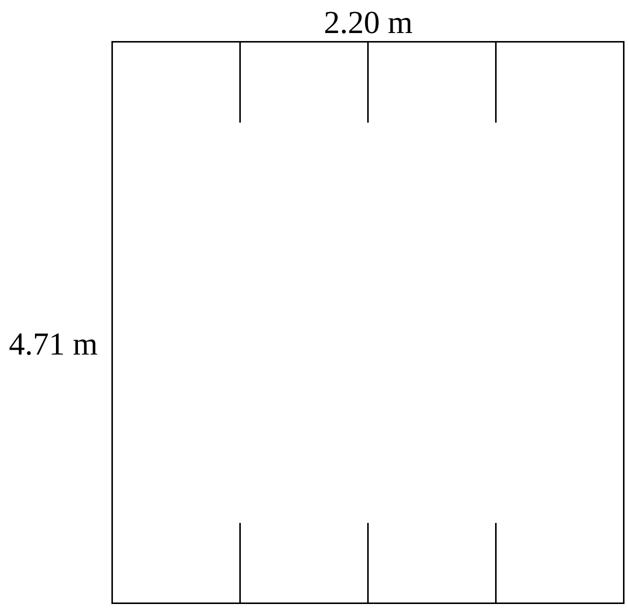


Figure 3. Group Housing pen design.



Group Housing

-Floor area/female	1.30 m²
-Feeder	Drop type, dropping into trough.
- Waterer	Trough waterer.

APPENDIX TABLES

Appendix Table 1. Descriptive statistics for sow housing system measures.

Item.	n	Mean	Standard Deviation	Minimum	Maximum
Body condition score:					
Allotment	1695	3.45	0.114	2.50	3.50
Day 60 of gestation	1319	3.46	0.105	2.75	3.50
Day 90 of gestation	1554	3.47	0.093	2.75	3.50
Farrowing	1599	3.42	0.134	2.75	3.50
Weaning	1461	3.27	0.201	2.50	3.50
Day 7 after breeding	1303	3.39	0.174	2.50	3.50
Sow Body weight (Sub-sample):					
Allotment (day 35 of gestation), kg	220	183.7	14.97	142.7	229.1
Farrowing, kg	209	229.1	20.25	172.3	280
Weaning, kg	175	187.5	15.34	144.5	231.8
Body weight gain-allotment to farrowing, kg	203	+45.1	14.78	+2.3	+85.9
Body weight gain-farrowing to weaning, kg	174	-41.6	16.19	-79.1	+2.7
Number of piglets per litter:					
Total born	1396	12.7	3.29	3.0	23.0
Born alive	1394	11.9	3.08	3.0	21.0
Born dead	1596	0.7	1.12	0.0	10.0
Born mummified	1599	0.2	0.55	0.0	6.0
After cross-fostering	1399	12.2	2.06	6.0	18.0
Weaned	1403	11.1	1.85	5.0	17.0
Litter birth weight, kg	1013	19.3	4.28	6.4	31.8
Piglet birth weight, kg	1006	1.5	0.24	0.76	2.28
Litter weaning weight, kg	1059	74.1	14.62	32.9	116.9
Piglet weaning weight, kg	1052	6.7	1.05	3.7	9.8
Wean to breeding interval, d	1323	8.9	10.18	2.0	87.0
Wean to re-breeding interval, d	73	53.4	18.50	25.0	98.0

CHAPTER 3: EFFECT OF FARROWING PEN SIZE ON PRE-WEANING MORTALITY

INTRODUCTION

For many years, most commercial facilities have housed sows and litters in farrowing pens with a sow crate. Furthermore, in the last 25 years it has been estimated that litter size has increased by 2 to 3 piglets. However, the farrowing pen size has not increased. The major cause of piglet mortality is crushing and increasing pen size would give more space for piglets and could reduce mortality. There has been no published research that has evaluated the effect of farrowing pen size on pre-weaning piglet mortality.

Therefore, the objective of this study is to compare the effect of standard with increased sized farrowing pens on pre-weaning mortality of piglets.

MATERIALS AND METHODS

This study used animals that were from the Gestation Housing System study and was carried out during the period that females were in the farrowing facility (i.e., from when they were moved to the farrowing facility until weaning) .

Experimental Design and Treatments

This study was carried out as a Randomized Complete Block Design with the blocking factor being farrowing room. Two farrowing pen size treatments were compared: 1) Standard (pen width = 1.52 m), 2) Increased (pen width = 1.68 m).

Animals and Allotment to Study

The animals used in this study had been housed during gestation in either individual crates or group pens (8 pigs/pen) (see Sow Housing System Animal Housing and Management section). A total of 526 bred females were used. Animals were allotted to farrowing pen size treatments when they were moved to the farrowing rooms on approximately day 112 of gestation. The farrowing rooms used for this study had pens that had the Increased pen width. Half of the pens in each room had a divider fitted to reduce the pen width to that for the Standard pen width treatment. For allotment to the study, females within a farrowing room were formed into outcome groups of 2 of the same sow housing treatment, and with similar parity (±1 parity), and farrowing date (± 2 days). Females were randomly allotted from within outcome group to 1 of the 2 pen width treatments. After allotment to treatment, the pen either had a divider inserted for sows on the Standard pen size treatment or were left without a divider for the Increased pen size treatment.

Animal Housing and Management

Animals in this study were housed and managed as previously described in the Sow Housing System Study (Animal Housing and Management section). The sow farrowing crate dimensions were previously described in the Sow Housing System Study. Farrowing rooms used in this study had different farrowing crate lengths of 2.07 m and 2.20 m. The different lengths led to different total pen areas: Standard treatment of 1.99 m^2 and 2.14 m^2; Increased treatment of 2.20 m^2 and 2.47. Piglet creep area varied depending on the length of the farrowing pen with sow crate and treatment, room 1 and 2 (Standard Pen Size - 1.99 m^2; Increased Pen Size – 2.20 m^2) was shorter than rooms 8 and 9 (Standard Pen Size – 2.14 m^2; Increased Pen Size – 2.47 m^2). Each sow and litter had one heat lamp that was held in place by a metal bar attached to the crate and extending away from the top of the crate in the center of the piglet space. An additional heat lamp was used in the winter (November-May) for the first few days after farrowing and was located in the middle of the pen on the opposite side of the farrowing crate to the first heat lamp. The farrowing crate in the Standard pens width was located in the center of the pen giving equal amount of piglet space on both sides of the crate. The farrowing crate in the Increased pens had the additional space located on the side of the first heat lamp.

Farrowing Measurements

The measurements taken during farrowing were previously described in the Sow Housing System Animal Housing and Management section.

Statistical Analysis

Normality and homogeneity of variance was tested using the PROC UNIVARIATE procedure of SAS (SAS Inst. Inc., NC). Data that was normally distributed were analyzed using the PROC MIXED procedures of SAS (Littell et al., 1996). Data that was not normally distributed were transformed using the PROC RANK procedures of SAS. Binary response data were analyzed using the PROC FREQ procedures of SAS using the chi-square test to evaluate differences between treatment means. The experimental unit was individual sow and litter for all measures and the model accounted for the fixed effects of treatment and random effects of replicate. Least-square means were separated by using the PDIFF option of SAS with treatment means being different at a $P \leq 0.05$.

RESULTS AND DISCUSSION

Litter performance

A total of 526 bred females were assigned to farrowing pen size treatments, with 263 females per treatment. Data were analyzed on 224 and 220 litters for the Standard and Increased pen size treatments, respectively. There were several reasons for litter performance data to be removed from the dataset prior to analysis; these reasons included: sows having all piglets cross-fostered off (42), discrepancies between numbers of piglets born and weaned (37), sows found not pregnant (1), and record removed as an outlier for total number of piglets born (4).

The effect of farrowing pen size treatment on litter performance is presented in Table 11. The Increased pen size treatment had a greater ($P < 0.05$) total number of piglets born per litter (13.4 piglets) compared to the Standard pen size treatment (12.9 piglets). In addition, there was a tendency ($P < 0.10$) for litter size after cross-fostering to be greater for the Increased pen size (12.7) compared to the Standard pen size (12.3). The Increased pen size had a greater ($P < 0.05$) number of piglets weaned per litter than the Standard pen size treatment (11.5 and 11.1, respectively), however, there was no difference ($P > 0.05$) between treatments for the number of piglets born alive, born dead, and born mummified. Furthermore, there was no difference (P > 0.05) between farrowing pen size treatments for pre-weaning mortality, total litter and average piglet weaning weight, and weaning age.

The treatment differences in the total number born per litter and in litter size after cross-fostering were not anticipated when this study was set up. Ideally litter size would be similar across the 2 treatments to make it relatively easy to interpret any treatment effects on piglet mortality and on number weaned per litter. Sows were randomly allotted to treatment within gestation sow housing treatment and, therefore, the difference in total born between the farrowing pen size treatments is most likely due to chance. Cross-fostering to equalize litter size between the farrowing pen size treatments was carried out within gestation housing system treatment and on this basis it would be expected that litter size after cross-fostering would be greater for the Increased pen size treatment which had a greater total number born. Similarly, the greater litter size at weaning for the Increased pen size treatment reflect the difference between the treatments for litter size after cross-fostering. Consequently, pre-weaning mortality would be the best variable to evaluate the effect on farrowing pen size treatments and this was not different between the two treatments which suggest that there was no benefit for the increased farrowing pen size. It should be born in mind, however, that this study was carried out with relatively young (mainly parity 0 and 1) and relatively small animals and research to evaluate the effect of farrowing pen size on pre-weaning mortality in older/bigger sows is warranted. In addition, power tests suggest that minimum of 2600 sows (1300/treatment) would need to be evaluated to have a high probability of finding that the difference in pre-weaning mortality found in the current study (0.6 percentage units) was statistically significant ($P \leq 0.05$). There were no previous studies found in the scientific literature that evaluated the effect of farrowing pen size, and, thus, no comparisons with previous research can be made.

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TABLES

Table 11. Effect of Farrowing Pen Size treatment on litter performance.

	Treatment			
Item	Standard	Increased	SEM	*P*-value
Number of litters	224	220	-	-
Number of piglets per litter:				
Born alive	12.1	12.4	0.21	0.19
Born dead[1]	0.6	0.8	-	0.20
Born Mummified[1]	0.1	0.2	-	0.94
Total born	12.9[b]	13.4[a]	0.21	0.03
After cross-fostering[2]	12.3	12.7	0.14	0.06
Weaned	11.1[b]	11.5[a]	0.12	0.02
Pre-weaning mortality, %[3]	10.1	9.5	-	0.51
Weaning weight, kg				
Total litter	74.0	75.9	0.98	0.11
Average piglet	6.7	6.7	0.07	0.48
Weaning age, d	22.0	22.1	0.16	0.25

[a,b]Means within a row with different superscripts differ ($P \leq 0.05$)

[1]Data were analyzed using PROC RANK procedure of SAS.

[2]Litter size is the number of piglets after cross-fostering.

[3]Data were analyzed using PROC FREQ procedure of SAS.

Table 12. The effect of farrowing pen size treatment on piglet mortality.

Item.	Treatment Standard	Increased	*P*-value[1]
Cause of mortality			
Low viability			
Number of piglets	3	4	-
Percentage of total mortality	1.1	1.5	0.66
Laid on			
Number of piglets	209	193	-
Percentage of total mortality	75.2	72.3	0.44
Starvation			
Number of piglets	8	10	-
Percentage of total mortality	2.9	3.8	0.57
Deformed			
Number of piglets	0	1	-
Percentage of total mortality	0.0	0.4	0.31
Shaker			
Number of piglets	2	4	-
Percentage of total mortality	0.7	1.5	0.38
Injury			
Number of piglets	3	2	-
Percentage of total mortality	1.1	0.8	0.69
Swollen joints			
Number of piglets	1	1	-
Percentage of total mortality	0.4	0.4	0.98
Unknown			
Number of piglets	9	9	-
Percentage of total mortality	3.2	3.4	0.92
Destroyed			
Number of piglets	8	12	-
Percentage of total mortality	2.9	4.5	0.31
Rupture-scrotal			
Number of piglets	0	1	-
Percentage of total mortality	0.0	0.4	0.31
Rupture-other			
Number of piglets	0	3	-
Percentage of total mortality	0.0	1.1	0.08
Other[2]			
Number of piglets	35	26	-
Percentage of total mortality	12.6	9.8	0.30
Total mortality	**278**	**266**	

[1]Data were analyzed using PROC FREQ procedure of SAS.
[2]Removal reason other represents all piglets without a cause of mortality recorded.

APPENDIX TABLES

Appendix Table 2. Descriptive statistics for farrowing pen size measures.

Item.	Descriptive statistics n	Mean	Standard deviation	Minimum	Maximum
Number of piglets per litter:					
Born alive	444	12.3	3.1	1.0	20.0
Born dead	444	0.7	1.18	0.0	9.0
Born mummified	444	0.2	0.52	0.0	6.0
Total born	440	13.2	3.11	4.0	21.0
Litter size[1]	444	12.5	2.05	6.0	18.0
Weaned	444	11.3	1.87	6.0	17.0
Litter weaning weight, kg	443	74.9	14.68	32.9	113.4
Average piglet weaning weight, kg	443	6.7	6.69	3.5	9.7
Weaning age	444	22.1	2.49	16.0	27.0

[1]Litter size is the number of piglets after cross-fostering.