Evaluation of well-being, productivity, and longevity of pregnant sows housed in groups in pens with an electronic sow feeder or separately in gestation stalls

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Objective—To compare well-being, performance, and longevity of gestating sows housed in stalls or in pens with an electronic sow feeder (ESF).

Animals—382 pregnant sows of parities 1 through 6.

Procedure—Sows were housed in separate stalls (n = 176) or group pens (206) with an ESF. Well-being of sows was assessed at various time points in terms of injuries, salivary cortisol concentration, and behavior in a novel arena or to a novel object. Farrowing performance and longevity of sows were also assessed.

Results—Total injury scores (TIS) of sows in pens were significantly higher at initial introduction and mixing. In stall-housed sows, TIS was significantly higher during late gestation. The TIS and cortisol concentration were significantly lower in stall-housed sows, compared with values for sows in pens. As parity increased, the likelihood of higher median TIS decreased significantly in pen-housed sows and increased significantly in stall-housed sows. The TIS of sows in pens was negatively correlated with body weight and backfat thickness, whereas these correlations were positive in stall-housed sows. Farrowing performance and results for novel arena or objects did not differ. Proportion of sows removed was significantly higher for pens than for stalls; lameness was the major reason for removal for both systems.

Conclusions and Clinical Relevance—Stalls impose space restrictions for larger sows, resulting in injuries during late gestation. Interventions are needed to minimize aggression during initial introduction and mixing and at the ESF in pens to reduce severe injuries or lameness of gestating sows. (*Am J Vet Res* 2005;66:1630–1638)

Housing systems for gestating sows are a major point of criticism for the swine industry. Concerns about the use of separate gestation stalls include restriction of freedom of movement and reduced social contact. Group housing of gestating sows in pens with mechanisms such as an **electronic sow feeder (ESF)** is being considered by producers who want to provide group housing while controlling feed intake of each sow.

Attempts to improve the well-being of sows by changing the housing system may not necessarily yield the expected benefits; rather, it is likely to provide another set of welfare issues. Therefore, it is important to evaluate various housing systems to be able to suggest alternatives. It is difficult to compare group housing systems with separate housing systems for each sow because of the multiplicity of criteria involved (eg, production, behavior, and physiologic variables)[1] and the lack of a single representative system of housing as a basis for comparison.[2] It would be more meaningful to characterize housing systems in a broader scope. To do this, it is essential to study a large range of aspects (eg, well-being, production, and longevity) for pens with an ESF and conventional stall systems.

Because animal well-being is a multidimensional variable, it is important to study several aspects of it. The use of health-related measures as tools for assessment of well-being is generally accepted because the effect of poor health is undisputable.[3] Injury is 1 health indicator. Similarly, when values for physiologic variables (eg, cortisol concentrations greater or less than the reference range for the species) and conditions under which the sample was collected are assessed, then these results could be indicative of stress.[4] Long-term intermittent stress can increase fear-related behavior when pigs are placed in a novel environment.[5] It has been suggested[6] that experimental conditions that allow free exploration are effective techniques for studying behavior. The behavior of sows when exposed to a novel arena or novel object may indicate housing-related stress experienced by the pigs. The study reported here was designed to determine the well-being of gestating sows in group pens with an ESF and conventional separate stalls in terms of injuries, salivary cortisol concentration, and behavior of sows in a novel arena or to a novel object. We also evaluated production performance and sow longevity.

Materials and Methods

Animals and housing—Adult sows (Yorkshire-Landrace crossbred; n = 382) were used in the study. Sows were weaned after a lactation of approximately 3 weeks and assigned to housing in a gestation stall or a pen with an ESF. Sows were housed in gestation stalls for the first 10 days after

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weaning before being moved to a gestation stall or a pen with an ESF.

One hundred seventy-six sows (body weight, 140 to 278 kg; parities 1 through 5) were allocated to housing in separate gestation stalls (length, 200 cm; width, 60 cm; height, 97 cm). Each stall[a] had a fully slatted concrete floor (12.6 cm in thickness; solid portion of 12.6 cm in width separated by slots of 2.5 cm in width) with a separate feeder and watering device for each stall. Two hundred six sows of the same genetic line (body weight, 171 to 259 kg; parities 1 through 4) were allocated to 4 pens. Each pen was 12.75 X 6.75 m and had a fully slatted floor. There were 40 to 55 sows/pen (the number of sows in each pen was 44, 55, 55, and 52, respectively). Each pen had a central walk-through ESF[b] and 3 watering bowls; the watering bowls were positioned on the partition between pens.

Sow identification was at the point of feed delivery for the ESF. Each sow was identified only when it put its head into the feeding bowl inside the ESF. Because there was no sow identification at the entry gate to the ESF, a sow was permitted entry into the ESF any number of times, even after receiving the daily allowance of feed. The entry gate of the ESF was electronically controlled, and it remained closed for 30 seconds when a sow that had already consumed the daily allotment of feed entered the ESF, after which time the door automatically opened to admit another sow.

Feeding procedures—Sows were fed 2.2 to 3.0 kg of feed daily (crude protein content, 15%), as determined on the basis of body weight and backfat thickness at time of weaning. Sows were fed a mean of 2.2 kg of feed from breeding to day 90 of gestation. The feed allowance was then increased to 2.4 kg from day 91 to 97 of gestation and increased again to 2.6 kg from day 98 to 109 of gestation, when they were moved into farrowing stalls. Sows were then fed 3 kg of feed/d until farrowing.

For the ESF, feed was offered to a sow in 100-g allotments at 35-second intervals; 25 mL of water was also provided with each feed delivery. Stall-housed sows were fed in accordance with the same feeding schedule by use of an automatic dry-feed drop system.[c] Sows in stall housing were provided feed only once daily.

Experimental design—All sows were weaned at (mean ± SE) 19.4 ± 0.05 days of lactation. Sows were housed in gestation stalls for the first 10 days after weaning before being moved to a gestation stall or a pen with an ESF. Sows that were in a pen system during the preceding gestation were allocated to pens again, and sows that were in stalls during the preceding gestation were again allocated to stalls.

Pigs were weaned at 2-week intervals in the unit; it required 2 batches of weaned sows (20 to 30 sows/batch) to complete the allocation of all sows for a single pen; thus, there were 2 dates of introduction and mixing for each pen. The first batch of sows was moved to the pens 5 days after breeding, and the second batch was moved to the pens 14 days after the first batch. When the allocation of sows for 1 pen was completed, the next pen was filled in the same manner. Therefore, the allocation of sows to each of the pens with an ESF was completed by weaning 8 batches of sows.

However, weaning of > 8 batches of sows was needed to complete the allocation of sows to stalls because of the limited availability of sows at the time the study was conducted. Some of the sows were allocated to the stalls when the unit had an outbreak of disease attributable to **porcine reproductive and respiratory syndrome virus (PRRSV)**.

All sows were artificially inseminated at the time estrus was detected and again 24 hours later. A vasectomized boar was used to aid in estrus detection.

Injury scoring—Injuries of each sow were evaluated on day 4 before weaning and days 5, 28, 56, 84, and 108 of gestation (day 0 = day of breeding). Injuries were scored by use of a scoring pattern reported elsewhere.[7] Injury scores were determined on the basis of frequency and severity of wounds at various body locations (right and left ear, snout, face, forehead, right and left shoulder, right and left forelimb, right and left side of the neck, right and left side of the thorax, right and left flank, top of the back [dorsum], udder, right and left hindquarters [sacral, gluteal, tuber coxae, rump, perineal, and anal regions], right and left hind limb, tail, and vulva). Wounds with a depth > 0.5 cm were considered deep wounds; wounds with a depth ≤ 0.5 cm were considered superficial wounds. Wounds were scored as follows: 0, no injury; 1, slight injury (< 5 superficial wounds); 2, obvious injury (5 to 10 superficial wounds, ≤ 3 deep wounds, or both); and 3, severe injury (> 10 superficial wounds, > 3 deep wounds, or both). Injury scores for each anatomic location were summed to yield a **total injury score (TIS)**. A single investigator (LA) performed injury scoring at all time points.

Assessment of salivary cortisol concentrations and behavioral testing—A subgroup of 80 sows (10 sows/batch; 40 assigned to pens with an ESF and 40 assigned to stalls) was randomly selected before weaning for use in assessment of salivary cortisol concentrations and novel arena-object testing (behavioral testing). Saliva samples were collected 4 days before weaning and at various stages of gestation; samples were collected from sows in pens with an ESF on days 5 and 19 (ie, the 2 days of introduction and mixing), 28, 56, 84, and 108 of gestation, whereas samples were collected from sows in stalls on days 5, 28, 56, 84, and 108 of gestation. Saliva samples were collected before injury scoring was performed.

Saliva samples were collected by use of a cotton swab[d] by allowing the sows to chew on the swab, which was clipped to a flexible thin metal rod, until the swab was thoroughly moistened. Care was taken to ensure the sows were not disturbed during the process of saliva collection. Saliva samples were collected between 10 AM and 11 AM on all collection days. The moistened cotton swabs were centrifuged at 400 X g for 5 minutes to extract the saliva, which was harvested and stored frozen at –20°C until analyzed. For analysis, approximately 0.5 mL of saliva was obtained from each swab. A solid-phase cortisol radioimmunoassy kit[e] was modified to measure cortisol concentrations in saliva.[8] All samples were analyzed in duplicate.

The injury scores of all sows and saliva of the subgroup of sows were collected 4 days before weaning and subsequently at various stages of gestation; sows in pens with an ESF were assessed on days 5 and 19 (ie, 2 mixing days), 28, 56, 84, and 108 of gestation, whereas sows in stalls were assessed on days 5, 28, 56, 84, and 108 of gestation.

A novel arena-object test (fear test) was conducted on day 108 of gestation for all subgroup sows in both housing systems before the sows were moved into farrowing stalls. Testing was conducted by modifying the method described in another study.[9] A completely enclosed rectangular arena (4.78 X 2.4 m) was divided into 10 equal segments, each of which was assigned a sequential number (ie, 1 through 10). A semicircle (radius, 0.5 m) was marked in the middle of the pen on the side opposite the entrance. The sows, which had never been in the rectangular arena prior to the test, were moved into the arena one at a time, directly from their gestation housing system.

Each sow was observed for 5 minutes. For the first 2 minutes, the segments a sow entered were recorded. The sow was considered to be in a segment when its snout entered the segment. After the initial 2 minutes, a novel object that the sow had never seen before was placed in the semicircle. The novel object was a fluorescent orange safety cone (74 cm in height with a base of 36 × 36 cm). The sow was observed for an additional 3 minutes after placement of the novel object. Data recorded during this time period included segments entered when the novel object was in the semicircle, time to approach the semicircle, total amount of time spent in the semicircle with the object, time to first interaction with the object, and number of interactions with the object. An interaction was defined as contact between the object and snout of the sow.

Productivity and longevity—Farrowing performance (ie, farrowing rate, litter size, number of stillborn pigs, number of mummified fetuses, birth weight of litter, and death of baby pigs before weaning) was recorded from a records database[f] of the research unit. Body weight and backfat thickness of sows were measured at weaning and days 28, 56, 84, and 108 of gestation. Backfat thickness was measured at the most caudal rib by use of an ultrasound unit.[g] Number of sows that died, were euthanatized, or were culled and the reasons for these events were also recorded.

Statistical analysis—Mean, SE, median, and range were used to describe the data. Considering the differences in housing systems, statistical comparisons of injuries and behaviors were made only within each housing system to highlight differences at various stages of gestation. Data on salivary cortisol concentration, productivity, and novel arena-object testing were compared between housing systems.

An ANOVA for repeated measures and Tukey pairwise comparisons were used to compare cortisol concentrations at various stages of gestation. A Friedman χ^2 test based on Cochran-Mantel-Haenszel statistics with rank scores (after adjusting to reduce the variation attributable to differences among sows) followed by nonparametric multiple comparison (comparison of mean ranks) was used to compare injury scores at various stages of gestation. The Spearman rank correlation was used to evaluate correlations of injury scores with cortisol concentration, body weight, and backfat thickness. The association between injury scores and parity was tested by use of a logistic regression model. For regression analysis, TIS was dichotomized by use of the median value (scores less than the median were designated as 0 and greater than or equal to the median were designated as 1). A χ^2 test was performed to study the association between stage of gestation and severity of injuries at various anatomic locations for sows in pens with an ESF. For stall-housed sows, the association between injuries or a lack of injuries at various anatomic locations and stage of gestation was analyzed because there was not a sufficient distribution of observations for various severity categories of TIS at the anatomic locations. An independent sample *t* test was performed to compare the production performance for sows in the 2 housing systems. Longevity and farrowing rate were compared by use of a 2-sample test for proportions. Results of the novel arena-object test were compared by use of an independent sample *t* test and Kruskal-Wallis ANOVA. All analyses were performed by use of computer software.[h] A value of $P \leq 0.05$ was considered significant for all comparisons.

Results

Mean number of sows that completed gestation for each pen ranged from 38 to 39. The remaining sows were detected as not pregnant and were removed from the study.

Median and range of TIS for all sows at various stages of gestation in stalls and pens with an ESF were summarized (**Table 1**). At all stages of gestation, TIS was lower in stall-housed sows than in pen-housed sows. Injuries of sows in stalls were mainly scratches or decubital ulcers, whereas sows in the ESF system had mainly bite wounds and wounds resulting from the slatted floors, especially on the distal part of the limbs and udder. In both systems, TIS was similar 4 days before weaning. On day 56 of gestation, TIS was significantly lower than the value at all other stages, except for the value on day 84 in sows in pens with an ESF. The TISs was similar on days in which sows were introduced and mixed in pens. The TISs on the second introduction and mixing day and day 108 of gestation were also similar. In stall-housed sows, the TIS was significantly higher on day 108 and there was no difference in TIS at other stages of gestation.

Frequencies of injuries on various body parts of sows housed in pens with an ESF differed significantly (χ^2 test) at various stages of gestation, except for injuries to the forehead and tail (**Table 2**). Higher percentages of injuries were detected on the neck, shoulder, thorax, hindquarters, and limbs. The percentage of observations of injuries on the udder and vulva increased during late gestation. An increased number of severe and obvious

Table 1—Median (range) values for total injury score (TIS)* for all sows and mean ± SE salivary cortisol concentration of a subgroup of sows at various stages of gestation when housed in groups in pens with an electronic sow feeder (ESF) or separately in gestation stalls.

		Day of gestation					
Variable	Before weaning	5	19	28	56	84	108
TIS							
Pens with an ESF†	4 (1–11)^{a}	25 (9–41)^{b}	22 (10–40)^{bc}	21(9–38)^{cd}	18 (7–34)^{e}	19 (7–39)^{de}	20 (7–38)^{cd}
Gestation stalls†	5 (1–11)^{a}	5 (1–16)^{a}	NA	5 (1–14)^{a}	4.5 (2–14)^{a}	5 (2–13)^{a}	6 (2–13)^{b}
Cortisol (ng/mL)							
Pens with an ESF†	0.54 ± 0.09^{a,A}	4.12 ± 0.54^{b,A}	3.14 ± 0.42^{b,c}	2.49 ± 0.23^{c,A}	2.11 ± 0.25^{c,C}	3.13 ± 0.48^{b,c,A}	4.24 ± 0.58^{b,A}
Gestation stalls†	1.21 ± 0.12^{a,B}	1.02 ± 0.15^{a,b}	NA	0.44 ± 0.07^{d,B}	0.45 ± 0.13^{d,D}	0.53 ± 0.07^{d,B}	0.95 ± 0.12^{a,B}

*Injury scores were determined for the right and left ear, snout, face, forehead, right and left shoulder, right and left forelimb, right and left side of the neck, right and left side of the thorax, right and left flank, top of the back (dorsum), udder, right and left hindquarters (sacral, gluteal, tuber coxae, rump, perineal, and anal regions), right and left hind limb, tail, and vulva. Wounds with a depth > 0.5 cm were considered deep wounds; wounds with a depth ≤ 0.5 cm were considered superficial wounds. Wounds were scored as follows: 0, no injury; 1, slight injury (< 5 superficial wounds); 2, obvious injury (5 to 10 superficial wounds, ≤ 3 deep wounds, or both); and 3, severe injury (> 10 superficial wounds, > 3 deep wounds, or both). Injury scores for each anatomic location were summed to yield a TIS. †Values differed significantly ($P < 0.001$) among time periods.

Day 0 = Day of breeding. NA = Not applicable.

[a-e]Within a row, values with different superscripts differ significantly ($P < 0.05$). [A,B]Within a column, values with different superscripts differ significantly ($P < 0.05$).

Table 2—Severity of injury at various anatomic locations and days of gestation in pregnant sows housed in pens with an ESF.

	No injury						Mild injury						Obvious injury						Severe injury					
Location	5	19	28	56	84	108	5	19	28	56	84	108	5	19	28	56	84	108	5	19	28	56	84	108
Face*†	63.2	78.7	78.7	91.0	93.6	94.8	20.7	14.9	20.0	9.0	5.8	5.2	14.9	4.5	1.3	0.0	0.6	0.0	1.2	1.9	0.0	0.0	0.0	0.0
Snout*‡	78.2	83.2	89.7	91.0	86.4	81.9	19.5	12.9	10.3	7.7	13.6	18.1	2.3	3.9	0.0	1.3	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0
Forehead*§	71.2	76.8	74.2	82.6	80.0	74.8	21.8	17.4	23.2	16.8	18.1	25.2	5.8	5.8	2.6	0.6	1.9	0.0	1.2	0.0	0.0	0.0	0.0	0.0
Ear†||	45.4	57.8	66.1	71.3	71.9	70.3	27.6	21.9	30.0	26.5	25.8	27.4	20.7	18.4	3.2	1.9	2.3	1.9	6.3	1.9	0.7	0.3	0.0	0.4
Neck†¶	17.8	25.2	34.2	47.7	50.3	45.8	17.8	25.1	37.7	34.2	32.9	38.7	23.6	21.3	22.0	16.1	14.8	13.6	40.8	28.4	6.1	2.0	2.0	1.9
Shoulder†¶	11.5	10.3	12.3	23.9	23.2	15.8	10.9	23.2	28.7	34.8	36.1	31.0	36.2	32.9	39.3	32.9	26.8	32.9	41.4	33.6	19.7	8.4	13.9	20.3
Thorax†¶	27.6	31.6	28.1	30.7	25.5	21.3	14.4	22.6	28.4	33.5	25.8	32.6	36.2	26.1	31.9	27.7	31.0	29.7	21.8	19.7	11.6	8.1	17.7	16.4
Flank†¶	47.1	47.1	41.6	44.2	36.8	45.8	17.8	26.1	32.9	36.1	39.0	31.6	23.6	19.4	18.7	18.1	21.3	17.7	11.5	7.4	6.8	1.6	2.9	4.9
Back||#	79.3	66.5	63.2	56.8	54.9	54.9	14.9	23.2	27.1	29.0	27.7	34.2	4.6	9.0	6.5	13.6	12.9	7.7	1.2	1.3	3.2	0.6	4.5	3.2
Hindquarters†¶	28.2	32.9	17.7	23.6	22.9	22.6	24.7	22.9	29.7	31.9	35.8	44.5	29.9	25.2	31.0	26.4	27.4	21.9	17.2	19.0	21.6	18.1	13.9	11.0
Forelimbs†||	21.3	26.8	30.0	35.5	29.0	31.0	56.3	58.4	56.8	50.0	63.9	62.3	20.7	13.2	11.9	13.9	5.8	6.7	1.7	1.6	1.3	0.6	1.3	0.0
Hind limbs†¶	14.4	11.6	9.4	10.0	14.5	14.9	39.7	49.0	55.2	57.1	57.1	62.1	39.6	32.3	27.7	27.1	21.6	17.2	6.3	7.1	7.7	5.8	6.8	5.8
Udder†¶	56.3	51.0	51.0	41.9	29.0	11.0	34.5	29.0	31.0	38.1	40.6	23.2	5.8	14.2	12.9	12.3	18.1	32.3	3. 4	5.8	5.1	7.7	12.3	33.5
Vulva†¶	63.3	53.6	56.1	62.0	44.5	18.1	24.1	34.2	30.3	23.2	32.3	36.8	10.3	7.7	9.7	11.6	13.5	18.0	2.3	4.5	3.9	3.2	9.7	27.1
Tail*§	57.5	56.8	61.3	63.2	65.2	64.5	33.3	38.1	31.6	31.0	30.3	32.9	9.2	4.5	7.1	5.2	4.5	2.6	0.0	0.6	0.0	0.6	0.0	0.0

Values reported are the percentage of injuries on various body parts.

*No injury versus injury (mild, obvious, and severe) was used for χ^2 analysis. †Severity of injury differed significantly ($P < 0.001$) among days of gestation. ‡Severity of injury differed significantly ($P < 0.05$) among days of gestation. §Severity of injury did not differ significantly ($P \geq 0.05$) among days of gestation. ||No injury, mild, and a third category of obvious and severe combined were used for χ^2 analysis. ¶All categories of injury were used for χ^2 analysis. #Severity of injury differed significantly ($P = 0.01$) among days of gestation.

Day 0 = Day of breeding.

Table 3—Injuries at various anatomic locations and days of gestation in pregnant sows housed separately in gestation stalls.

	No injury					Injury				
Location	5	28	56	84	108	5	28	56	84	108
Face*	84.9	85.6	85.6	91.8	84.9	15.1	14.4	14.4	8.2	15.1
Snout*	79.4	86.3	87.7	85.6	83.6	20.6	13.7	12.3	14.4	16.4
Forehead*	86.3	84.3	88.4	92.5	90.4	13.7	15.7	11.6	7.5	9.6
Ear*	90.8	90.4	93.5	92.5	89.7	9.2	9.6	6.5	7.5	10.3
Neck*	92.5	94.5	93.8	92.1	89.7	7.5	5.5	6.2	7.9	10.3
Shoulder†	67.8	70.2	75.3	76.7	78.4	32.2	29.8	24.7	23.3	21.6
Thorax‡	94.5	94.9	90.4	87.7	86.3	5.5	5.1	9.6	12.3	13.7
Flank‡	96.2	95.2	91.4	87.7	85.6	3.8	4.8	8.6	12.3	14.4
Back†	60.3	49.3	50.0	42.5	44.5	39.7	50.7	50.0	57.5	55.5
Hindquarters‡	81.9	74.0	68.8	69.2	67.5	18.1	26.0	31.2	30.8	32.5
Forelimbs†	59.2	65.1	69.9	70.2	61.0	40.8	34.9	30.1	29.8	39.0
Hind limbs*	61.6	56.5	62.0	66.8	64.4	38.4	43.5	38.0	33.2	35.6
Udder‡	59.6	69.9	67.8	39.7	30.1	40.4	30.1	32.2	60.3	69.9
Vulva†	93.8	98.0	98.6	93.8	92.5	6.2	2.0	1.4	6.2	7.5
Tail*	82.2	80.8	91.8	87.0	86.3	17.8	19.2	8.2	13.0	13.7

*Severity of injury did not differ significantly ($P \geq 0.05$) among days of gestation. †Severity of injury differed significantly ($P < 0.05$) among days of gestation. ‡Severity of injury differed significantly ($P < 0.001$) among days of gestation.

Day 0 = Day of breeding.

injuries were evident at the time of introduction and mixing in pens. As gestation advanced, severity of injury (obvious and severe) decreased in all body parts, except for the udder and vulva, where it increased during late gestation (days 84 and 108 of gestation) in sows housed in pens with an ESF.

In stall-housed sows, a higher percentage of injuries was noticed on the top of the back (dorsum), forelimbs, hind limbs, and udder (**Table 3**). Percentage of observations of injuries on the flank, thorax, top of the back, hindquarters, forelimbs, vulva, and udder increased significantly as gestation advanced. There was a significant decrease in injuries on the shoulder as gestation advanced. On day 108 of gestation, the top of the back (dorsum) and udder had the highest percentage of injuries.

Logistic regression analysis revealed that as parity increased, the likelihood for higher median TIS decreased significantly in sows in pens with an ESF (**Table 4**). The odds ratio was 0.56, 0.34, and 0.53, respectively, for sows in parities 2, 3, and ≥ 4, compared with that for sows in parity 1. Although the likelihood for a higher median TIS increased with increasing parity for stall-housed sows, it did not differ significantly among parities. The TIS of sows in pens with an ESF was significantly and negatively correlated with body weight (*r*, –0.068) and backfat thickness (*r*, –0.087), whereas TIS of sows in stalls was significantly ($P = 0.01$) and positively correlated with body weight (*r*, 0.204) and backfat thickness (*r*, 0.093).

For the subgroup of sows used for assessment of salivary cortisol concentrations, only 36 sows in pens with an ESF and 29 sows in stalls could be included for data analysis. The remaining 15 sows in the subgroup were not pregnant and were removed from the study.

The salivary cortisol concentrations at first introduction and mixing and on day 108 of gestation were significantly higher than the concentrations on days 28 and 56 of gestation for sows in pens with an ESF (Table 1). The lowest cortisol concentration for sows in pens was detected 4 days before weaning; this value was significantly lower than values for all other time periods. In stall-housed sows, cortisol concentration was significantly higher before weaning and on days 5 and 108 of gestation, compared with values for other stages of gestation. At all stages of gestation, cortisol concentrations were lower in stall-housed sows than in pen-housed sows. There was no significant correlation between TIS and cortisol concentration for either housing system.

Table 4—Odds ratio (OR) and 95% confidence interval (CI) for the relationship of parity with likelihood of a TIS that is greater than the median TIS for pregnant sows housed in group pens with an ESF or housed separately in gestation stalls.

	Group pens with an ESF		Gestation stalls	
Variables	**OR**	**95% CI**	**OR**	**95% CI**
Parity 2 vs parity 1	0.56[a]	0.34–0.94	1.23[b]	0.72–2.12
Parity 3 vs parity 1	0.34[a]	0.20–0.57	1.18[b]	0.77–1.80
Parity ≥ 4 vs parity 1	0.53[a]	0.32–0.87	1.31[b]	0.87–1.97

[a]Significant association. [b]Non-significant association.

We did not detect significant differences between the housing systems for the novel arena-object test. However, stall-housed sows entered a greater number of squares (before and after addition of the novel object), had less time to the first interaction, and had a greater number of interactions, compared with results for sows in pens with an ESF (**Table 5**).

We did not detect significant differences in productivity and longevity between sows housed in pens with an ESF and sows housed in stalls with regard to farrowing rate, litter size, number of pigs born alive per litter, number of stillborn pigs per litter, and number of pigs foster mothered by a sow (**Table 6**). Stall-

Table 5—Results for a novel arena-object test conducted on pregnant sows housed in groups in pens with an ESF or housed separately in gestation stalls.

Variable	Pens with an ESF	Gestation stalls
No. of sows tested	36	29
No. of segments entered during exploration period*	12.5 (5–22)	13 (3–26)
No. of segments entered during novel object test*	12.5 (1–25)	14 (3–35)
No. of sows that entered semicircle containing the novel object	13	16
Time required for sows to enter semicircle containing the novel object (s)†	112.62 ± 13.00	72.50 ± 15.61
Time sows spent in the semicircle containing the novel object (s)†	11.46 ± 3.66	11.88 ± 2.91
Time to first interaction with the novel object (s)†	2.31 ± 0.89	2.05 ± 0.44
No. of interactions with the novel object*	1 (0–8)	2.5 (0–20)

*Values reported are median (range). †Values reported are mean ± SE.

Table 6—Longevity and production performance of pregnant sows housed in groups in pens with an ESF and housed separately in gestation stalls.

Variable	Pens with an ESF	Gestation stalls
Longevity (No. of sows)		
Total	206	176
Farrowed	154	144
Culled because of nonpregnancy*	33	26
Culled because of lameness	11[a]	1[b]
Aborted	2	1
Other†	6	4
Production performance‡		
Litter size (No. of baby pigs)	10.88 ± 0.27	10.98 ± 0.29
Born alive/litter (No. of baby pigs)	9.10 ± 0.28	9.36 ± 0.28
Stillborn/litter (No. of baby pigs)	0.92 ± 0.11	0.94 ± 0.11
Mummies/litter (No. of mummies)	0.86 ± 0.16	0.67 ± 0.14
Litter weight at birth (kg)	14.39 ± 0.41	14.8 ± 0.40
Preweaning mortality (%)§	13.16 ± 1.41[c]	16.24 ± 2.22[d]
Fostered to other sows (No. of baby pigs)	0.79 ± 0.13[c]	0.67 ± 0.11[d]
Fostered to sow (No. of baby pigs)	0.88 ± 0.12	0.77 ± 0.13
Farrowing rate (%)	74.76	81.81

*Sows were not pregnant because they returned to estrus after mating. †Other includes sows that were excluded from the study because they were detected in estrus after breeding. ‡Values reported are mean ± SE. §Value calculated as follows: (No. of baby pigs that died before weaning/No. of baby pigs born alive) × 100.

[a,b]Within a row, values with different superscript letters differ significantly ($P = 0.05$). [c,d]Within a row, values with different superscript letters differ significantly ($P < 0.01$).

housed sows had significantly fewer mummies per litter and significantly fewer pigs that were transferred to a foster mother, compared with values for sows in pens with an ESF. Preweaning mortality rate was significantly lower for pen-housed sows. For pen-housed sows, the proportion of sows culled was significantly higher, compared with the proportion culled for stall-housed sows. The proportion of sows culled for lameness in the pen system was also significantly higher, compared with the proportion of stall-housed sows culled for lameness. The major reasons for culling of sows in pens with an ESF were lameness and poor reproductive performance.

Discussion

During the preweaning period, the sows were housed separately in farrowing stalls that differed structurally from the gestation stalls in terms of floor type (floor of the farrowing stalls was cast iron) and dimensions (214 × 66 cm, excluding a creep area for baby pigs). Housing of sows in farrowing stalls corresponded to lower TIS values for sows during the preweaning period.

Injuries in sows housed in pens with an ESF were mainly caused by 2 factors, fighting subsequent to initial introduction and mixing of sows to establish social hierarchy[10,i] and fighting for entry to the ESF. Most of the injuries in sows housed in pens with an ESF during the introduction and mixing period were located on the neck, ears, shoulder, thorax, flank, and hindquarters because these body parts were more likely to be injured as a result of parallel and inverse parallel encounters during fighting. The higher number of limb injuries at the time of introduction and mixing may have resulted from pigs chasing each other on the slatted floor during fighting. Once a social hierarchy is established, agonistic interactions decrease in frequency and intensity,[i] and subordinate sows tend to avoid dominant sows, rather than a situation in which dominant sows attack submissive sows.[11,12]

Competition for entry into the ESF also contributed to injuries in the pen-housed sows. In pens with an ESF, only a single sow can eat at a time, resulting in a highly competitive environment and possible aggression.[13] Competition to enter the ESF at the start of a feeding cycle typically is intense. In addition, social facilitation motivates sows to enter the ESF,[14,15] even after receiving the daily allotment,[16] which leads to competition to enter the ESF. These aggressive interactions were not as intense as those at the time of introduction and mixing and may not have caused severe injuries, such as those seen at the time of introduction and mixing. With advancing gestation and consequent increases in metabolic demand, sows may be hungrier and make more attempts to enter the ESF, thus resulting in aggressive encounters. It has been suggested[17] that although the amount of feed during gestation is usually sufficient for maintenance of the sow, growth of the sow and fetal development result in increased motivation to eat.

With advancing gestation, body parts such as the udder and vulva became engorged and are easily injured during aggressive encounters. The chances of a swollen vulva being injured increase when sows queue for entry to an ESF. Once the vulva is injured, it is more likely to receive additional bite wounds because the swollen labia or dark color from hemorrhage attract more attention from other sows.[18] The prevalence proportion of sows with vulva injuries reportedly[19] increases from farrowing to the end of gestation, especially during the last 3 weeks before farrowing. These feeder-related aggressions may have been responsible for the increase in injury scores after midgestation in sows in pens with an ESF in the study reported here, despite the fact that there were no new sows introduced or additional mixing of sows at that time.

Design of the ESF in the study reported here, with the control at the point of feed delivery and not at the entry gate, was 1 factor responsible for the increased number of vulva injuries for sows in the ESF system. Once a sow entered the ESF after consuming its daily allowance, it was difficult for it to move backward and leave the ESF, especially when the sow behind it was pushing forward attempting to enter the ESF. In such instances, the hindquarters of the sow in front (ie, the sow already in the ESF) are most vulnerable to bite wounds.

Although competition and consequent aggression are likely when the number of sows exceeds the capacity of an ESF, this did not appear to be related to aggression in the study reported here because there were only about 45 sows/ESF, whereas the capacity for each ESF was 60 sows. However, the system in this study allowed sows entry into the ESF even though they had already consumed their daily allotment of feed, and this created a competitive environment for sows attempting to enter the ESF to eat feed, if any, left by the preceding sow. Thus, an improvement in the system could be to add a tag reader on the entrance gate in an attempt to keep out sows that have already eaten. This would also prevent sows from sleeping in the ESF.

The engorged udder of a sow in advanced gestation may be injured when the sow lies on a slatted floor. The higher number of injuries in the udder and vulva at later stages of gestation may explain the higher TIS toward late gestation than at midgestation in sows in pens with an ESF.

Similar to results for the ESF system, udder injuries contributed a large proportion of the injuries during the late stages of gestation in stall-housed sows. In addition, there were more injuries on the top of the back during later stages of gestation in stall-housed sows. Increased prevalence of injuries on the flank, thorax, and hindquarters with advancing gestation was attributed to an increase in body size associated with the developing pregnancy and consequent reduction in space availability within the stall for movements. Although relative measurements of stall-to-sow size were not assessed in the study reported here, investigators in another study[20] indicated that sows are likely to be injured when they make postural adjustments within a restricted space. In addition, the authors of that study[20] reported that injuries on the top of the back result from the back of a sow being pressed forcefully against the bars on the sides of the stall during lateral recumbency because of inadequate stall width in relation to height of the sow. Lying down and standing up are movements mainly supported by the forelimbs, and these postural changes on slatted floors can result in injuries.

Analysis of our observations during the study suggested that interactions with the feeder at the front of each stall (ie, stepping on the feeder) may also have caused injuries to the forelimbs of stall-housed sows, although we did not collect data on the cause of lameness. However, shoulder injuries resulted from prolonged lateral recumbency in the farrowing stalls, and these injuries resolved with time. Injuries to the vulva and hindquarters resulted when sows moved backward in the stall during postural changes. However, the severity and number of all these injuries were less in stall-housed sows than in pen-housed sows.

Sows housed in separate farrowing stalls with their litters and the use of ad libitum feeding did not have opportunities for aggressive interactions with other sows. There was no possibility that a sow in a farrowing stall would have physical contact with the sows in adjacent farrowing stalls. In addition, sows have a progressive decrease in cortisol concentration during lactation,[21,22] which explains the low preweaning salivary cortisol concentrations in sows in the study reported here.

The increase in cortisol concentration on days when sows were introduced and mixed in pens with an ESF could have been related to the stress associated with aggressive encounters performed to establish or reestablish social hierarchy. The cortisol concentrations for the 2 days on which sows were introduced and mixed in pens were not different because the cause of the increase in cortisol concentration was the same for both days. Once hierarchy is established, there are fewer aggressive interactions because it is a tendency of submissive sows to move away from dominant sows, and only a threat behavior by a dominant sow would be sufficient to maintain the hierarchy,[i] which may explain the reason for the decrease in cortisol concentrations after the introduction and mixing period, compared with concentrations for the other stages. However, aggression and associated stress related to entry to the ESF persisted.

An increase in cortisol concentration toward the later stages of gestation could have been attributable to hungrier sows in later stages of gestation competing more actively for entry to the ESF, resulting in more stress in those animals. Fetal initiation of cortisol production during late gestation may also have contributed to the increase in cortisol concentration during late-stage gestation. Fetal pigs initiate the increase in cortisol in late gestation in preparation for farrowing. There are increased amounts of fetal[j] and maternal[23] cortisol in swine toward the end of gestation. The increase in cortisol concentration toward later stages of gestation in stall-housed sows could have been preparatory to farrowing. However, the cortisol concentration in stall-housed sows during late gestation was lower than that in pen-housed sows during late gestation, which may have been attributable to the fact that sows in gestation stalls were not affected by additional factors such as aggression or competition for entry to an ESF.

An outbreak of disease attributable to infection with PRRSV and stress of immunization during the time of the study reported here could have caused an increase in cortisol concentration in stall-housed sows during the preweaning period and day 5 of gestation for the last 3 replicates (mean ± SE preweaning cortisol concentrations in saliva were 0.684 ± 0.079 ng/mL, 1.315 ± 0.151 ng/mL, 1.958 ± 0.252 ng/mL, and 1.008 ± 0.222 ng/mL for replicates 1, 2, 3, and 4, respectively). Saliva samples from the second, third, and fourth replicates were collected at the time of the outbreak. Data collected during this period were also included for analysis; of 5 similar time points of comparison for the housing systems, the only time point affected by the outbreak attributed to infection with PRRSV was the preweaning period. However, during the preweaning period, all sows in both housing systems were in farrowing stalls.

The association between parity and TIS was mediated through growth in the size of the sows with increase in parity and consequent increase in body weight, especially in younger-parity sows. Sows with increased body weight are the dominant sows in a group[24] and rarely receive aggression from other group members. This explains the negative associations of TIS with parity, body weight, and backfat thickness observed in the study reported here. A negative association between parity and injuries in group-housed sows has also been reported in other studies.[7,24,25] Body dimensions can be expressed as a function of live weight.[26] When body weight increases with an increase in parity in stall-housed sows, the available space within the stall is reduced, which increases the chance of injury during typical postural adjustments.[20] These observations may explain the positive correlations of TIS with body weight and backfat thickness in stall-housed sows.

Although stall-housed sows appeared to be more explorative in the novel arena, the results were inconclusive. Sows varied widely in their behavior to the novel arena and object. In another study,[6] sows from substrate-impoverished conditions required a longer time to enter a novel test arena and begin interacting with a novel object, compared with the time required by sows from substrate-enriched conditions. Although not comparable with the experimental settings in that study,[6] stalls in our study may have been considered more barren than the group pens; hence, the findings reported here do not agree with observations of that preceding study. Furthermore, we could not account for the excitement displayed by stall-housed sows when allowed a short walk and a large area to explore. The possibility for wide variations in response among sows on the basis of breed (eg, lean hybrids vs other breeds) has been suggested.[27] Similarly, the response of a sow may vary with its degree of previous exposure to humans and various environments, depending on the category of farm (eg, research herd vs commercial herd).

The higher proportion of sows culled for lameness in the ESF system is a major welfare concern because lameness is a condition associated with pain. Most of the lameness among sows in pens with an ESF was evident after the aggressive interactions associated with introduction and mixing of sows in pens with slatted floors. Fighting among newly introduced sows on slatted floors without bedding is likely to result in a high incidence of lameness,[28,29] which is unlikely in sows housed separately in gestation stalls. The number of stall-housed sows culled was less than the number of pen-housed sows. Lameness is a major reason for culling of sows from swine herds,[30,31] and a reduction in the incidence of lameness could have decreased the culling rates for sows housed in gestation stalls.

Higher preweaning mortality rate for stall-housed sows than for pen-housed sows in the study reported here was contradictory to higher preweaning mortality rate in group-housed sows in other studies.[32-34] The outbreak of disease attributable to PRRSV at the time of the study in some replicates for stall-housed sows may have caused the higher preweaning mortality rate in that group of sows. Sows in both housing systems in the study received the same care and management, and the variation in management and stockmanship needs to be considered when comparing results of studies.

Gestation stalls are designed to provide sows with protection from aggression. However, analysis of results of the study reported here suggested that stalls impose severe restrictions on movement because of limited space during late gestation, and this restriction is sufficient to cause notable injuries. The possibility of aggression at the time of introduction and mixing and at ESF entry makes pens with an ESF a challenge for gestating sows, as evident from the number of injuries during early and late gestation. Although pens offer freedom of movement, analysis of our results indicated that the ESF system needs to be revised to improve benefits for sow well-being. The novel arena-object test appeared to be of limited use in this study because it was difficult to consider factors such as differences among sows, excitement of stall-housed sows, and effects of painful lameness conditions, or the interaction of these factors, on the response of sows.

a. Gestation stall, Crystal Spring Hog Equipment Ltd, St Agathe, MB, Canada.
b. Electronic sow feeder, Osborne Industries Inc, Osborne, Kan.
c. Dry-feed drop system, Chore-Time Equipment, Milford, Ind.
d. SARSTEDT, Aktiengesellschaft & Co, Numbrecht, Germany.
e. Coat-A-Count TKCO, Diagnostic Products Corp, Los Angels, Calif.
f. PigCHAMP software, PigCHAMP, Ames, Iowa.
g. Lean-Meater, Renco Corp, Minneapolis, Minn.
h. SAS software, version 8.2, SAS Institute Inc, Cary, NC.
i. Hessing MJC. *Individual behavioural characteristics in pigs and their consequences for pig husbandry*. PhD thesis, Agricultural University, Wageningen, The Netherlands, 1993.
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