Pre-weaning mortality of piglets in a bedded group-farrowing system

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Summary

By retrieving sow performance data from 5 years of production, we evaluated factors that related to pre-weaning mortality of piglets in a bedded group-farrowing system. Data were collected on 421 litters that were weaned at 4 to 5 weeks of age. Average live litter size at birth and weaning was 11.5 and 8.9 pigs, respectively, resulting in an overall pre-weaning mortality rate of 22.6%. A reduction in piglet mortality was observed over the course of the study ($P < .001$), which may be attributed to improvement in management practices. During summer months, piglet mortality was greater than during other seasons (30% versus 22% ± 2.2%; $P < .01$). Average pre-weaning mortality of piglets born to younger sows was lower than in those born to mature sows (19% versus 29% ± 2.3%; $P < .001$). Large variation in piglet mortality among individual sows was observed, and the between-sow difference showed some consistency across parities ($R_{rep} = 0.25$). Results of this study suggest that by implementing good management practices, alleviating heat stress, increasing the proportion of younger sows, and removing sows with high piglet mortality in early parities, piglet mortality in group-farrowing systems can be reduced.

Keywords: swine, pre-weaning mortality, group farrowing

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Resumen - Mortalidad en maternidad en lechones en un sistema de cama con partos en grupo

Al recuperar la información sobre el desempeño de hembras de 5 años de producción, evaluamos factores relacionados con la mortalidad de lechones antes del destete en un sistema de cama con grupos de parto. Se recolectó información de 421 camadas que fueron destetadas entre 4 y 5 semanas de edad. El promedio de lechones vivos al nacimiento y destetados fue de 11.5 y 8.9 cerdos, respectivamente, resultando en un porcentaje de mortalidad al destete de 22.6%. Se observó una reducción en la mortalidad de lechones durante el curso del estudio ($P < .001$), la cual puede atribuirse a la mejora en las prácticas de manejo. Durante los meses de verano, la mortalidad de lechones fue mayor que durante las otras estaciones (30% contra 22% ± 2.2%; $P < .01$). El promedio de mortalidad al destete de los lechones nacidos de hembras más jóvenes fue más bajo que en los nacidos de hembras adultas (19% versus 29% ± 2.3%; $P < .001$). Se observó una gran variación en la mortalidad de lechones entre hembras individuales, y la diferencia entre hembras mostró algo de consistencia entre paridades ($R_{rep} = 0.25$). Los resultados de este estudio sugieren que al implementar buenas prácticas de manejo, mitigar el estrés de calor, aumentar la proporción de hembras jóvenes, y quitar las hembras con alta mortalidad de lechones en paridades tempranas, se puede reducir la mortalidad de lechones en un sistemas de partos en grupo.

Résumé - Mortalité pré-sevrage de porcelets dans un système avec mise-bas en groupe sur litière

En compilant les données de performance de truies de 5 années de production, il a été possible d'évaluer les facteurs liés à la mortalité pré-sevrage chez les porcelets dans un système avec mise-bas en groupe sur litière. Les données ont été récoltées à partir de 421 portées qui ont été sevrées à l'âge de 4 à 5 semaines. La taille moyenne des portées vivantes à la naissance et au sevrage était respectivement de 11.5 et 8.9 porcelets, ce qui donnait un taux global de mortalité pré-sevrage de 22.6%. Une réduction de la mortalité chez les porcelets a été observée au cours de l'étude ($P < .001$), et pourrait être attribuable aux améliorations apportées dans les pratiques de gestion d'élevage. Au cours des mois d'été, la mortalité des porcelets était plus élevée qu'au cours des autres saisons (30% vs 22% ± 2.2%; $P < .01$). La mortalité moyenne pré-sevrage des porcelets nés de truies plus jeunes était inférieure à celle de porcelets nés de truies matures (19% vs 29% ± 2.3%; $P < .001$). De grandes variations dans la mortalité des porcelets parmi les truies individuelles étaient observées, et la différence inter-truie a montré une certaine constance au fil des parités ($R_{rep} = 0.25$). Les résultats de l'étude suggèrent que la mortalité des porcelets dans les systèmes de production avec mise-bas en groupe peut être réduite en mettant en place de bonnes pratiques de régie, en diminuant le stress associé à la chaleur, en augmentant la proportion de truies plus jeunes, et en retirant les truies avec des taux de mortalité élevés chez les porcelets dans les premières parités.

Due to consumers' concerns about food safety and the environmental impact of pork production, as well as animal well-being in the swine industry, the demand for niche pork, such as that naturally or organically produced, has increased dramatically over the last decade.[1] The basic requirements of producing niche pork include no antibiotics, no artificial growth promotants, no animal by-products in the feed, no gestation stalls, and loose-farrowing systems.[2] Among these requirements, loose-farrowing systems that require sows to farrow in large pens with bedding materials have become the bottleneck of niche pork production,

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due to the high pre-weaning mortality of piglets.[3] Piglet mortality in loose-farrowing systems commonly ranges from 20% to 33%,[4,5] which is about twofold greater than that normally occurring in confinement farrowing crates. The major cause of piglet mortality in a loose-farrowing system is piglets being laid on by sows, which is usually referred to as piglet crushing.[5,6] The problem of piglet crushing is not only an economic loss, but a welfare concern, as nearly 70% of crushed piglets are otherwise healthy and viable.[7]

Because loose-farrowing systems in the United States are usually adopted by small-scale producers, data sets documenting sow performance are small. A survey of 40 producers using loose-farrowing systems in the midwestern United States indicated that average pre-weaning mortality of piglets was 26.4% and average litter size weaned was 6.7.[3] Due to variation in genotype, nutrition, housing, and management practices, this survey could not provide detailed information on factors contributing to piglet deaths. To determine causative factors of piglet mortality with the ultimate goal of seeking solutions to the problem, the following study was conducted. The objectives of this study were to quantify piglet mortality in a bedded, group-farrowing system, to assess seasonal effects on pre-weaning mortality of piglets, to evaluate effects of parity on piglet mortality, and to determine variation in piglet mortality among individual sows.

Case description

The study was conducted by retrieving production data collected at the University of Minnesota's West Central Research and Outreach Center in Morris, Minnesota, from 2003 to 2008.

Animals, facilities, and management

The research and outreach center has a 60-sow farrow-to-finish alternative housing facility. All barns were bedded with wheat straw. Gestating sows were housed in groups of 30 (4.0 m^2 of bedded area per sow) with access to individual feeding stalls. Sows farrowed in a group-farrowing system where eight sows shared a communal area and farrowed in individual open pens. Over the 5 years of the study period, a total of 433 litters were farrowed by 191 sows. Among the 191 sows (parities 1 to 10) involved in the study, 76 (40%) farrowed once, 50 (26%) farrowed twice, and 65 (34%) farrowed three to six times in the system. The average parity of sows was 2.8.

The farrowing facility consisted of three identical rooms housing eight sows each (24 total). Each farrowing room measured 9.2 × 11.0 m with a solid concrete floor. Each room had two dry-feeders with three feeding spaces each, two cup drinkers, and a communal dunging area. Eight individual pens, measuring 1.8 × 2.4 m, were set up in each room during farrowing. Each pen was bedded with straw to a depth of about 15 cm. An open door, measuring 66 cm (width) × 75 cm (height), was installed at the center of the front panel 27 cm above the floor, which allowed the sow to exit and enter the pen freely. After farrowing, a roller was placed at the bottom of each pen door (Figure 1), with the top of the roller 35 to 40 cm above the floor to prevent piglets from crawling out of the pen. With the roller in place, the door opening was 62 cm in height. Pens did not provide anti-crush rails, supplemental heating, or creep areas. Room temperature was controlled by a heating system and ventilation fans to achieve a room temperature of 20°C during the farrowing period. However, during summer months, the target temperature was exceeded because of high outdoor temperatures.

Sows were moved to farrowing rooms 2 to 7 days before their expected farrowing dates. To avoid mixing-induced aggression, sows from one gestation pen were allocated to the same farrowing room. Gilts were housed separately from sows during gestation, and moved to one of the farrowing rooms dedicated to gilts. Sows and gilts farrowed in individual farrowing pens of their own choosing. Minimal cross-fostering was conducted within 24 hours after farrowing to reduce live litter sizes greater than 14 pigs. Approximately 10 days after the last sow farrowed in a room, farrowing pens were removed. During the period between pen removal and weaning, sows and their litters within each room were housed as a group on a bedded floor. Piglets were weaned between 28 and 35 days of age.

Prior to farrowing, sows and gilts were limit-fed on the concrete floor of the communal area to ensure all sows were eating. Every morning, 2.8 kg per sow of a lactation diet formulated according to National Research Council (NRC)[8] recommendations was provided. Limit-feeding continued until all sows in the room had farrowed. Once all sows in a room farrowed and appeared to be eating normally, sows were allowed ad libitum access to feed

Figure 1: A group-farrowing room housing eight sows prior to bedding. Sows selected their own farrowing pens. All sows farrowed within a 3-day period. A roller (white bar) was placed on the threshold of each door after farrowing to prevent piglets from crawling out of the pen. The farrowing pens were removed approximately 10 days after the birth of the last litter in the room.

in the feeders. Since sows within a room farrowed in a 3-day period, the period of feed restriction lasted between 1 and 4 days postpartum for an individual sow.

Record of performance of lactating sows

The number of live-born and stillborn piglets was recorded for each litter within 24 hours after birth. Stillborn piglets were identified visually by the amount of mucus on the mouth and snout. Beginning in 2006 and continuing through 2008, stillborn pigs were further confirmed by postmortem examination. Within 24 hours after completion of farrowing, lung tissues of dead pigs were floated in cold water to assess the presence of air in the tissues. If there was no air in the tissues, it was determined that the pigs had not breathed after birth, and stillbirth was confirmed. The number of piglets cross-fostered into or out of a litter and the actual number of pigs suckling from each sow was recorded. Daily from birth to weaning, piglets in each litter were counted and dead piglets were registered and removed. At weaning, litter weight and the number of pigs in each litter were recorded, from which an average piglet weight was calculated. Piglet mortality was based on the number of pigs that died between birth and weaning, calculated as a percentage of total pigs born alive adjusted by the number of cross-fostered pigs.

Feed intake of sows was estimated by feed disappearance, which was monitored on a room basis. The amount of feed added to each room during lactation was recorded. Average daily feed intake (ADFI) during the period when sows were allowed ad libitum access to feed was estimated, based on total feed disappearance and the number of sow-days recorded for each room. Beginning in 2006 and continuing through 2008, 178 sows from eight farrowing groups were weighed individually before entry into the farrowing rooms and at weaning.

Data analysis

Data were sorted by farrowing year, season, and sow parity. The farrowing system began operation in 2003, with only 24 litters farrowed in the system during that year. Consequently, data collected during 2003 were combined with data from 2004 and that period was referred to as 2003-2004. For a similar reason, data for 2008 (n = 24) were combined with data collected in 2007 and that period was referred to as 2007-2008. On the basis of the actual farrowing dates, each farrowing group was assigned to a farrowing season. Each season represented 3 months, ie, winter was from December to February, spring from March to May, summer from June to August, and fall from September to November. Within each farrowing group, sows were categorized as parities 1, 2, 3, and 4+.

All data were tested for normal distribution. Feed intake and body weight were distributed normally and were analyzed using the Mixed Procedure of SAS software (Version 9.1, SAS Institute, Inc, Cary, North Carolina). Remaining data were not distributed normally and were analyzed using the GLIMMIX Procedure of SAS (Version 9.1). To determine factors contributing to piglet mortality, the year of farrowing, farrowing season, and parity were used as fixed effects, and farrowing group and room were included as random effects. In analysis of litter performance, litter was used as the experimental unit because litters remained in individual pens until 10 days after farrowing. During this time, about 90% of the total piglet deaths occurred. Body weight and feed intake of sows were analyzed using individual sow and room as the experimental units, respectively. Differences among the means were tested by Student's *t*-test for the Proc Mixed model and the Tukey test for the GLIMMIX model, and considered significant when $P < .05$.

To evaluate variation in piglet mortality among individual sows, sows that farrowed in the system three to six times were identified. Since this subset of the data approached normal distribution, the ANOVA procedure of SAS (Version 9.1) was used to analyze variation among individual sows. To evaluate the consistency of sow difference across parities, repeatability (R_{rep}) was estimated[9,10] using the following equation: $R_{rep} = S_A^2/(S^2+S_A^2)$, where S_A^2 is the among-sow variance and S^2 is the within-sow variance. The among-sow variance (S_A^2) = (MS_B - MS_W) ÷ n, where MS_B is the between-sow mean squares, MS_W is the within-sow mean squares obtained from one-way ANOVA, and n is the average number of farrowings of each sow in the group-farrowing system.[9] The within-sow variance (S^2) = MS_W.

Changes in piglet mortality over the 5 years

Of the 433 litters farrowed, 12 litters were cross-fostered to other sows at farrowing due to health or reproductive problems of the sows. Consequently, data collected on the remaining 421 litters were analyzed and are presented here. Overall, average live litter size at birth was 11.5 pigs, and litter size at weaning was 8.9 pigs, resulting in 22.6% overall pre-weaning mortality.

A reduction in piglet mortality was observed over the course of the study ($P < .001$; Table 1). In 2005, 3.8 pigs per litter died before weaning, but this death rate declined to 2.2 pigs per litter in 2007-2008 ($P < .001$). As a result, the number of piglets weaned per litter increased from 8.1 to 9.2 ($P = .03$). As this was not a controlled study, no treatment factors were applied or tested to reduce piglet mortality. However, over the years, effort had been made in sow management to improve piglet survival. We presume that changes made in sow management may have contributed to the reduction in piglet mortality. Four management changes were implemented in 2006 to reduce piglet mortality. One of the first changes implemented was delaying processing of piglets (ear notching, iron injections, and castration) until 3 days after the last sow in the room had farrowed. Prior to this, individual litters were processed 24 hours after birth. Delayed processing decreased the disturbance of other sows that might be farrowing in the room and kept noise to a minimum throughout farrowing. Our second change included delaying sow entry to farrowing rooms until 2 days before the expected farrowing date, instead of 7 days before the expected date as in earlier years. This practice helps to keep the bedding in farrowing pens dry and clean, which provides a comfortable nest for sows and piglets during farrowing and early lactation. A dry and clean nest can keep piglets warm during the first days of life, which is beneficial to piglet survival.[11] The third change focused on retaining piglets in the farrowing pen until the pen was removed, which likely contributed to the reduction in piglet mortality. The roller on the bottom of each pen door was raised from 35 cm to 40 cm above the floor and remained in place until the pen was removed. Prior to this change, some large piglets could get out of the pen a few days before the pen was removed. When this happened, the roller was removed from the pen to allow piglets free passage in and out of the pen. However, as litters did not always stay intact, some piglets missed a nursing bout, which may have contributed to decreased vigor of piglets. By raising the roller to 40 cm above the floor and keeping it in place until the pen was removed, we successfully confined the entire litter in the farrowing pen to ensure that all piglets were present at nursing. Our final management change related to effectiveness of stockpeople. As barn staff became more familiar with the system, they became more adept at spotting and correcting problems. Proper animal handling based on good animal-stockperson relationships, spending more time in the barn to closely observe sows and litters, promptly identifying and treating sick sows, and fostering piglets from problem sows when necessary, are all skills that improved in the labor force and likely contributed to reducing piglet mortality in this loose-farrowing system. All changes in management practices were implemented at about the same time, and coincided with the reduction in pre-weaning mortality of piglets. We believe the changed practices contributed to increased piglet survival in this loose-farrowing system, but cannot attribute the improvement to any specific changes.

Feed intake of sows decreased from the earlier years to the recent years ($P < .05$). This was not expected, and the reason for it is not clear.

Effects of farrowing season

During summer months, piglet mortality was higher than during other seasons ($P < .01$; Table 2), which was consistent across the 5 years of the study period. Consequently, sows weaned 1.4 fewer piglets in the summer than in the winter. The high piglet mortality observed during the summer may have been associated with heat stress. Since no cooling systems were present in the barn, the average daily maximal room temperature over the first week postpartum was 28°C during summer months. With straw bedding, sows had a difficult time dissipating heat to the environment, which exacerbated heat stress. In response to heat stress, sows reduced feed intake. Our feeding record indicated that during summer months, ADFI of sows was lower than during other seasons ($P < .05$). The reduced intake was associated with lighter litter weight at weaning, which may indicate poor milk production.[12] Heat stress in sows may also result in difficult farrowing, which is associated with a higher stillborn rate.[13] We observed that the number of stillborn piglets tended to be greater in the summer compared with other seasons ($P = .08$). We also noted a few cases of piglets retained in the uterus during summer months, but none during any other seasons. Hence, alleviating heat stress may reduce seasonal variation in piglet mortality observed in the current study.

Effects of sow parity

Compared with sows in the first and second parities, sows in parities 3 and 4+ had higher piglet mortality ($P < .001$; Table 3). The older sows lost approximately one more piglet per litter than the younger sows ($P < .001$). As a result, sows in the first parity weaned the largest litters (9.6 pigs per litter), while sows of parity 4+ weaned the smallest litters (8.1 pigs per litter; $P < .001$). Born-alive litter size was largest

Table 1: Sow and litter performance over 5 years in a group-farrowing system

Parameter	Year					
	2003-2004	2005	2006	2007-2008	Pooled SE	*P*
No. of farrowing groups	7	5	5	6	NA	NA
No. of farrowing rooms	9	13	15	18	NA	NA
No. of litters farrowed	72	100	119	142	NA	NA
No. of litters weaned	72	100	115	134	NA	NA
Mean parity of sows	2.7	2.7	2.7	2.9	0.61	.72
Body weight of sows (kg)*						
Before farrowing	ND	ND	224^{a}	303^{b}	21.7	.02
At weaning	ND	ND	233	247	7.5	.23
ADFI of sows (kg/d)†	7.9^{a}	6.7^{ab}	6.5^{b}	6.1^{b}	0.40	.04
No. of pigs/litter						
Live born	11.9	11.8	11.5	11.0	0.29	.19
Stillborn	0.8	0.8	0.6	0.6	0.14	.47
Nursing pigs‡	11.9	11.8	11.6	11.4	0.31	.71
Dead§	3.1^{ab}	3.8^{b}	2.6^{a}	2.2^{a}	0.31	< .001
Weaned	8.9^{ab}	8.1^{a}	9.0^{ab}	9.2^{b}	0.34	.03
Mortality (%) ¶	24.4^{ab}	30.0^{a}	21.8^{b}	18.6^{b}	2.23	< .001
Weaned litter weight (kg)	70	66	78	84	6.8	.16
Weaned pig weight (kg)	7.8	8.4	8.7	9.2	0.75	.67

* Measured on 178 sows in eight farrowing groups during the years 2006 to 2008.

† Room was the experimental unit.

‡ Number of piglets in each litter after cross-fostering.

§ Number of piglets that died between birth and weaning at 28-35 days of age.

¶ Number of dead pigs as a percentage of the nursing pigs.

ADFI = average daily feed intake; NA = not applicable; ND = not done.

abc Means with no common superscript within a row differ ($P < .05$; Student's *t*-test for body weight and feed intake, Tukey test for numbers of piglets and mortality).

Table 2: Effect of farrowing season on piglet mortality in a group-farrowing system

Parameter	Farrowing season					
	Winter	Spring	Summer	Fall	Pooled SE	*P*
No. of farrowing groups	6	6	4	7	NA	NA
No. of farrowing rooms	13	14	12	16	NA	NA
No. of litters farrowed	127	95	78	133	NA	NA
No. of litters weaned	125	94	74	128	NA	NA
Mean parity of sows	2.8	2.4	3.0	2.7	0.61	.23
Body weight of sows (kg)*						
Before farrowing	223[a]	ND	259[ab]	307[b]	24.9	.06
At weaning	233	ND	235	249	8.7	.34
ADFI of sows (kg/d)†	7.4[c]	7.0[c]	5.7[d]	7.2[c]	0.40	.03
No. of pigs/litter						
Live born	12.0	11.2	11.5	11.5	0.32	.44
Stillborn	0.6[ab]	0.7[ab]	1.0[a]	0.5[b]	0.14	.08
Nursing pigs	12.0	11.4	11.6	11.8	0.28	.57
Dead	2.7[a]	2.7[a]	3.6[b]	2.7[a]	0.31	.07
Weaned	9.4[c]	8.7[cd]	8.0[d]	9.1[c]	0.34	.01
Mortality (%)	21.1[c]	21.7[c]	30.0[d]	22.2[c]	2.22	.01
Weaned litter weight (kg)	79[cd]	88[d]	59[c]	73[cd]	6.8	.02
Weaned pig weight (kg)	8.4	9.9	7.6	8.1	0.75	.17

* Measured on 178 sows in eight farrowing groups during the years 2006-2008.

† Room was the experimental unit.

ADFI = average daily feed intake; NA = not applicable; ND = not done.

ab Means with no common superscript within a row tend to differ ($P < .10$; Student's *t*-test for body weight and feed intake, and the Tukey test for number of piglets and mortality).

cd Means with no common superscript within a row differ ($P < .05$).

in parity 3 sows, and smallest in sows in parities 2 and 4+. Large born litter size may be associated with light birth weight of piglets, which may increase the risk of early piglet death.[14,15] Since birth weight was not monitored, it was not clear how litter size affected birth weight of piglets in this study. After cross-fostering, the difference in litter size among parities was diminished, except that sows in parity 2 had smaller litters. Nevertheless, sows of parities 3 and 4+ lost more piglets than younger sows in the loose-farrowing system. This could be partially attributed to the body size of sows. As parity increases, the body size of sows is also increased. Other researchers[6,16] have noted that pre-weaning mortality of piglets in loose-farrowing systems increased with an increase in body length of sows. Older sows also had more stillborn pigs compared with sows in the first and second parities ($P < .01$), similar to that observed in confinement farrowing systems.[17]

Variation in piglet mortality among individual sows

Among the 191 sows involved in the study, 65 farrowed three to six times (mean parity = 3.3, range = 1-10) in the group-farrowing system. Large variation in piglet mortality among individual sows was detected ($P < .001$). The consistency of the sow difference across parities was evaluated by repeatability. The estimated repeatability was 0.25, indicating that 25% of the variation in piglet mortality was associated with differences among individual sows. This agrees with earlier studies.[9,10] Jarvis et al[10] reported that sow differences in piglet crushing were consistent across parities in farrowing crates, with a repeatability of 0.14. With large variation in piglet mortality among individual sows (ranged from 0% to 70% in the current study) and a repeatability of 0.25, selecting sows with low piglet mortality could be a promising approach to solve the problem of piglet mortality in the group-farrowing system. Sows with high piglet mortality during the early parities should be culled because these sows probably will have the same problem in the later parities.

Implications

- Under the conditions of this study, piglet mortality is higher in summer than in the other seasons, and older sows lose more piglets than younger sows.
- Variation in piglet mortality among individual sows can be passed to the following parities.
- Results of this study suggest that pre-weaning mortality of piglets in loose-farrowing systems can be reduced by applying good management practices, alleviating heat stress, reducing the percentage of old sows in the herd, and removing dams with high piglet mortality in early parities.

References

1. Honeyman MS, Pirog RS, Huber GH, Lammers PJ, Hermann JR. The United States pork niche market phenomenon. *J Anim Sci*. 2006;84:2269–2275.

*2. Our Pork. Husbandry Protocols. Available at **http://www.nimanranch.com**. Accessed 6 January 2010.

*3. Kliebenstein J, Stender D, Mabry J, Huber G. Costs, returns, production and financial efficiency of niche pork production in 2006. Iowa Pork Industry Center, Iowa State University, Ames, Iowa. 2007. Available at: **http://www.ipic.iastate.edu/information/Production.numbers.NRI2006.pdf**. Accessed 9 November 2009.

4. Edwards SA. Perinatal mortality in the pig: environmental or physiological solutions? *Livest Prod Sci*. 2002;78:3–12.

5. Dunn N. Positive aspects of no-crate farrowing. *Pig Progr*. 2005;21:20–24.

6. Damm BI, Forkman B, Pedersen LJ. Lying down and rolling behavior in sows in relation to piglet crushing. *Appl Anim Behav Sci*. 2005;90:3–20.

7. Spicer EM, Driesen SJ, Fahey VA, Horton BJ, Sims LD, Jones RT, Cutler RS, Prime RW. Causes of pre-weaning mortality on a large intensive piggery. *Aust Vet J*. 1986;63:71–75.

Table 3: Effect of sow parity on piglet mortality in a group-farrowing system

Parameter	Sow parity					
	1	2	3	4+*	Pooled SE	*P*
No. of litters farrowed	124	93	81	135	NA	NA
No. of litters weaned	123	89	80	129	NA	NA
Body weight of sows (kg)†						
Before farrowing	254	244	262	291	26.7	.55
At weaning	198^{a}	232^{b}	251^{c}	277^{d}	5.8	< .001
No. of pigs/litter						
Live born	11.8^{ab}	11.1^{a}	12.2^{b}	11.1^{a}	0.32	.02
Stillborn	0.6^{ab}	0.5^{a}	0.8^{ab}	1.0^{b}	0.13	.01
Nursing pigs	11.9^{a}	11.0^{b}	12.1^{a}	11.7^{ab}	0.25	.02
Dead	2.4^{a}	2.2^{a}	3.5^{b}	3.6^{b}	0.31	< .001
Weaned	9.6^{a}	8.8^{ab}	8.6^{b}	8.1^{b}	0.32	< .001
Mortality (%)	18.8^{a}	19.1^{a}	28.1^{b}	28.9^{b}	2.27	< .001
Weaned litter weight (kg)	74	78	74	73	4.4	.35
Weaned pig weight (kg)	7.7^{a}	8.7^{b}	8.7^{b}	9.0^{b}	0.40	< .001

* Parity 4+ included sows in parities 4 through 10.

† Measured on 178 sows in eight farrowing groups during the years 2006-2008.

NA = not applicable.

[abcd] Means with no common superscript within a row differ ($P < .05$; Student's *t*-test for body weight, and the Tukey test for number of piglets and mortality).

8. National Research Council. *Nutrient Requirements of Swine*. 10th ed. Washington, DC: National Academy Press; 1998:119–122.

9. Valros A, Rundgren M, Spinka M, Salonieme H, Algers B. Sow activity level, frequency of standing-to-lying posture changes and anti-crushing behavior – within sow-repeatability and interactions with nursing behavior and piglet performance. *Appl Anim Behav Sci*. 2003;83:29–40.

10. Jarvis S, D'Eath RB, Fujita K. Consistency of piglet crushing by sows. *Anim Behav Welf*. 2005;14:43–51.

11. Herpin PM, Damon J, Dividich L. Development of thermoregulation and neonatal survival in pigs. *Livest Prod Sci*. 2002;78:25–45.

12. McNamara JP, Pettigrew JE. Protein and fat utilization in lactating sows: I. Effects on milk production and body composition. *J Anim Sci*. 2002;80:2442–2451.

13. Sprecher DJ, Leman AD, Dziuk PD, Cropper M, DeDecker M. Causes and control of swine stillborns. *JAVMA*. 1974;165:698–701.

14. Milligan BN, Fraser D, Kramer D. Birth weight variation in the domestic pig: effects on offspring survival, weight gain and suckling behavior. *Appl Anim Behav Sci*. 2001;73:179–191.

15. Quiniou N, Dagorn J, Gaudre D. Variation of piglets' birth weight and consequences on subsequent performance. *Livest Prod Sci*. 2002;78:63–70.

16. Marchant JN, Rudd AR, Mendl MT, Broom DM, Meredith MJ, Corning S. Timing and causes of piglet mortality in alternative and conventional farrowing systems. *Vet Rec*. 2000;19:209–214.

17. Moeller SJ, Goodwin RN, Johnson RK, Mabry JW, Baas TJ, Robison OW. The National Pork Producers Council Maternal Line National Genetic Evaluation Program: A comparison of six maternal genetic lines for female productivity measures over four parities. *J Anim Sci*. 2004;82:41–53.

*Non-refereed references.