5-2007

Performance of gestating sows in bedded hoop barns and confinement stalls

Peter J. Lammers
Iowa State University

Mark S. Honeyman
Iowa State University, honeyman@iastate.edu

John W. Mabry
Iowa State University, jmabry@iastate.edu

Jay D. Harmon
Iowa State University, jharmon@iastate.edu

Performance of gestating sows in bedded hoop barns and confinement stalls

Abstract

The effects of gestation housing systems on sow and litter performance were evaluated for 2.5 yr in southwest Iowa. Gestation housing system treatments were as follows: 1) individual gestation stalls in a mechanically ventilated confinement building with a partially slatted floor and a manure flush system and 2) group pens with individual feed stalls in deep-bedded, naturally ventilated hoop barns. In all, 957 litters from 353 sows were evaluated. Number of pigs born alive per litter differed for the 2 housing treatments ($P = 0.002$). Sows gestated in hoop barns gave birth to more live pigs per litter (10.0 ± 0.2 pigs) than sows gestated in stalls (9.3 ± 0.2 pigs). Preweaning mortality was not different for the 2 housing treatments ($P = 0.70$). Cross-fostering was done to equalize litter size within 24 h of birth, which resulted in an equal number of weaned pigs per sow ($P = 0.50$) regardless of gestation housing treatment. The weaning-to-breeding interval was different ($P = 0.01$), with sows kept in stalls (4.3 ± 0.6 d) returning to estrus sooner than sows gestated in hoop barns (6.0 ± 0.6 d). These results indicate that gestating sows can be housed as groups in deep-bedded hoop barns equipped with individual feeding stalls and will perform comparably to gestating sows housed in confinement systems with individual gestation stalls.

Keywords

Animal Science, alternative swine housing, group gestation

Disciplines

Agriculture | Animal Sciences | Bioresource and Agricultural Engineering

Comments

This article is from *Journal of Animal Science* 85, no. 5 (May 2007): 1311–1317, doi: 10.2527/jas.2006-437. Posted with permission.

JOURNAL OF ANIMAL SCIENCE
The Premier Journal and Leading Source of New Knowledge and Perspective in Animal Science

Performance of gestating sows in bedded hoop barns and confinement stalls

P. J. Lammers, M. S. Honeyman, J. W. Mabry and J. D. Harmon

J ANIM SCI 2007, 85:1311-1317.
doi: 10.2527/jas.2006-437 originally published online January 15, 2007

Performance of gestating sows in bedded hoop barns and confinement stalls[1]

P. J. Lammers,* M. S. Honeyman,*[2] J. W. Mabry,* and J. D. Harmon†

*Department of Animal Science, and †Department of Agricultural and Biosystems Engineering, Iowa State University, Ames 50011

ABSTRACT: The effects of gestation housing systems on sow and litter performance were evaluated for 2.5 yr in southwest Iowa. Gestation housing system treatments were as follows: 1) individual gestation stalls in a mechanically ventilated confinement building with a partially slatted floor and a manure flush system and 2) group pens with individual feed stalls in deep-bedded, naturally ventilated hoop barns. In all, 957 litters from 353 sows were evaluated. Number of pigs born alive per litter differed for the 2 housing treatments ($P = 0.002$). Sows gestated in hoop barns gave birth to more live pigs per litter (10.0 ± 0.2 pigs) than sows gestated in stalls (9.3 ± 0.2 pigs). Preweaning mortality was not different for the 2 housing treatments ($P = 0.70$). Cross-fostering was done to equalize litter size within 24 h of birth, which resulted in an equal number of weaned pigs per sow ($P = 0.50$) regardless of gestation housing treatment. The weaning-to-breeding interval was different ($P = 0.01$), with sows kept in stalls (4.3 ± 0.6 d) returning to estrus sooner than sows gestated in hoop barns (6.0 ± 0.6 d). These results indicate that gestating sows can be housed as groups in deep-bedded hoop barns equipped with individual feeding stalls and will perform comparably to gestating sows housed in confinement systems with individual gestation stalls.

Key words: alternative swine housing, group gestation

J. Anim. Sci. 2007. 85:1311–1317
doi:10.2527/jas.2006-437

INTRODUCTION

Historically, sows have usually been kept in groups, often with outdoor access. In 2001, 64% of the US sow herd was gestated in stalls in confinement buildings (USDA, 2001). It is likely that this percentage has not decreased and may be even greater today. Gestation stalls allow controlled feed intake and individual monitoring of health and stage of pregnancy. Typical gestation stalls measure 2.2 × 0.6 m (Svendsen and Svendsen, 1997). Although the narrow width of gestation stalls facilitates maximum stocking density within a capital-intensive confinement building, sow movements are restricted (Barnett et al., 2001), and natural behavior patterns are altered (Jensen and Wood-Gush, 1984; Stolba and Wood-Gush, 1989). The public perception of animal welfare has led to legislation in Europe and the United States relative to gestation sow housing (Moynagh, 2000; Snelson, 2005). European legislation prohibits keeping gestating sows individually confined for extended periods of time and takes effect in January 2013 (European Union, 2001).

Several researchers have reported lower productivity for sows kept in groups compared with sows gestated in individual stalls (den Hartog et al., 1993; Barbari, 2000). Other researchers have shown that keeping sows in groups does not lower productivity and for some measures improves reproductive performance (England and Spurr, 1969; Morris et al., 1998; Bates et al., 2003). In a study by Connnor et al. (1997) comparing group pens inside a conventional gestation barn to pens in a deep-bedded hoop barn, Canadian workers reported that sow performance was not affected by housing. Hoop barns are attracting the interest of pig producers in the midwestern United States as lower capital-cost structures for gestating sows (Harmon et al., 2004).

The purpose of this study was to compare sow and litter performance for 2 gestation housing systems in Iowa, i.e., individual gestation stalls in a confinement

[1]This project was supported by Hatch Act and State of Iowa funds, USDA Special Grants, Wallace Foundation for Rural Research and Development, and the Leopold Center for Sustainable Agriculture. We gratefully acknowledge the assistance of R. Breach, D. Hummel, D. Kent, and the former staff of the Iowa State University Lauren Christian Swine Research Farm for data collection and N. Leyva-Estrada for statistical assistance. Mention of company or product names is for clarity and does not imply endorsement by the authors or Iowa State University nor exclusion of any other products that may be suitable for application.

[2]Corresponding author: honeyman@iastate.edu

Received July 5, 2006.
Accepted January 8, 2007.

Table 1. Ambient temperatures for Atlantic, Iowa[1]

Item, °C	Long-term[2]			Trial period (March 2001 to September 2003)	
	Annual	Fall-winter[3]	Spring-summer[4]	Fall-winter[3]	Spring-summer[4]
Avg temperature	9.4	0.2	18.6	1.0	19.0
Avg maximum temperature	15.7	6.2	25.3	7.5	25.9
Avg minimum temperature	3.1	–5.7	12.1	–5.4	12.2

[1]Mesonet, 2005.
[2]Long-term = 30-yr averages for this location.
[3]Fall-winter = October through March.
[4]Spring-summer = April through September.

building, and group pens with individual feed stalls in deep-bedded hoop barns.

MATERIALS AND METHODS

Facilities

The effects of gestation system on sow and litter performance were evaluated at the Iowa State University Lauren Christian Swine Research and Demonstration Farm near Atlantic for 2.5 yr (March 2001 through September 2003). Table 1 presents both long-term and trial-specific ambient temperature information for Atlantic (Mesonet, 2005). The gestation housing system treatments were as follows: 1) individual gestation stalls in a mechanically ventilated confinement building with a partially slatted floor and a manure flush system and 2) group pens with individual feeding stalls in deep-bedded, naturally ventilated hoop barns. The confinement facility was more than 15 yr old and had been updated in the late 1990s. The 2 gestation hoop barns were built in the late 1990s.

The 2 hoop barns (32.9 × 9.1 m) were oriented north to south with a 4.5-m-wide raised concrete pad spanning the entire length of the western wall of each building. Standard (2.1 × 0.51 m) feeding stalls were set on the concrete pad. An access alley ran the length of the building in front of the stalls. The feeding stalls were equipped with rear gates that were closed at the time of feeding to limit feeding aggression and variations in feed intake. The feed stalls also opened at the front, allowing the transfer of individual animals from the hoop barn to the farrowing facility. The concrete pad was 0.76 m above the finished grade of the bedded area, allowing the stalls to remain bedding-free. During summer, a sprinkler system was used to periodically wet the concrete pad. The sprinkler system was activated when the interior temperature of the hoop barn reached 26°C. Sows could cool themselves through contact with the concrete and the evaporation of water. A bedding pack of cornstalks was always maintained in the eastern portion of the hoop barns.

Earlier Iowa work with swine in hoop barns has shown that temperatures inside of hoop barns are generally 3 to 5°C warmer during the fall and winter months (October through March) and 1 to 2°C cooler during the spring and summer months (April through September) than the outside ambient air temperature (Honeyman et al., 2001; Honeyman and Harmon, 2003). If given the opportunity, sows will maintain distinct areas for lounging and defecation (Stolba and Wood-Gush, 1989). Sows housed in hoop barns in the current experiment were also observed to maintain distinct areas for lounging and defecation by herdsmen. A frost-free waterer was placed on a raised platform along the eastern wall of the hoop barns. Semipermanent fencing was set east to west at the midpoint of the barn, subdividing each 32.9-m hoop barn into 2 pens housing 32 sows each. There was an individual feeding stall for each sow in a given pen, and the sows were allowed to use this area for lounging as well. Within each hoop barn, there was 3.44 m^2/sow, with 1.08 m^2 of individual feeding stall and the remaining 2.36 m^2 as bedded area.

The confinement facility was a mechanically ventilated building that had been updated in the late 1990s to house 120 gestating sows. Four rows of individual stalls (2.1 × 0.6 m) ran the length of the building. Each stall had an individual nipple waterer and was equipped with a dripper for cooling the sow during the summer. Drippers were activated when the interior temperature of the barn reached 26°C. During the fall and winter (October through March), the interior temperature of the confinement facility was maintained at or above a minimum temperature of 18°C. Feed was delivered to individual stall troughs via an automated auger system. The front two-thirds of each stall was solid concrete flooring, whereas the rear third was slatted. Urine and feces dropped to a shallow pit below the sows that was periodically flushed to a larger holding basin outside of the building.

Animal Management

All practices involving animals were approved by the Iowa State University Animal Care and Use Committee.

The sow genotype was 25% Hampshire × 50% Yorkshire × 25% Landrace. Multiparous sows were randomly assigned to a gestation housing system treatment when the project commenced. All first-parity gilts were gestated in individual stalls and randomly assigned to a gestation cohort after breeding for the second parity. This practice was followed to minimize the size differential and aggression among the sows within the group housing system.

Farrowing occurred every 2 wk throughout the year in 1 of 4 farrowing rooms on the farm. Farrowing rooms were in a mechanically ventilated building with raised crates and a manure flush system. Sows were moved as a group to farrowing rooms within 4 d of their expected parturition. Sows were washed and disinfected before entry into the farrowing crates. Sows were also weighed and 10th-rib backfat was determined at the P2 location using a Renco Lean-Meter (Renco Corp., Minneapolis, MN). Sow vaccinations were for parvovirus-leptospirosis-erysipelas, *Escherichia coli*, and clostridial scours (FarrowSure and Litterguard LT, Pfizer Animal Health, New York, NY). Sows were dewormed twice per year with ivermectin (Merial Ltd., Iselin, NJ) in the feed.

At farrowing, the number of pigs born alive, stillborn pigs, and mummified pigs were recorded. Litter birth weight of the live pigs was also recorded. Cross-fostering within 24 h of birth was done to equalize litter size within a farrowing room. Cross-fostering across gestation housing treatments was allowed. Weaning occurred at 17 to 21 d of age. At weaning, the litter was counted and weighed before being moved to a climate-controlled nursery facility. At weaning, sows were also weighed, and their 10th-rib backfat at the P2 location was measured (Renco Lean-Meter; Renco Corp.). Changes in BW and backfat depth between entrance into the farrowing crate and weaning were then calculated.

After weaning, the sows were moved into a central confinement breeding barn with a slatted floor. Beginning 4 d after weaning, heat detection with a mature boar was performed daily. Sows were artificially inseminated at 24 and 48 h after estrus detection. Insemination was accomplished in the presence of a mature boar. All sows in the study were inseminated with Duroc semen from a commercial boar stud. Semen was delivered to the farm within 24 h of collection 2 to 3 times weekly. After mating, the sows were allocated to 1 of the 2 gestation systems based on the production schedule. If possible, sows that had previously gestated in hoop barns were returned to hoop barns, and sows that had previously gestated in individual stalls returned to individual stalls. Sows were moved as a group to their assigned gestation housing treatment by 9 d after weaning.

To match production conditions, equally sized groups were gestated in the hoop barns. Each hoop barn had 2 pens housing 32 sows each; thus, groups of 32 sows were placed in a particular pen within 1 of the 2 hoop barns by 9 d after weaning. Sows that had been gestated in the hoop barns previously were checked for estrus 4 d after weaning, and those that displayed estrus were inseminated and returned to the group pens in the hoop barns. Other sows that had been weaned and mated at the same time were added as needed to maintain the group size when the sows were moved from the breeding barn to the gestation housing. To conserve resources and match typical production practices that keep facilities as full as possible, sows that conceived within 9 to 70 d after weaning were reincorporated into a later group. Sows were allowed to transfer from 1 gestation housing treatment to the other after breeding, but not at midgestation. Once a group of 32 sows had been established within a pen inside a hoop barn, no replacement sows were added until the group had farrowed and the piglets were weaned.

During gestation, every sow received 2.04 kg/d of a corn-soybean meal diet that met the daily nutritional requirements (NRC, 1998). During the last third of gestation, the feed allowance was increased to 2.72 kg/d. Baseline feeding was increased seasonally (November through March) by 25% for sows housed in the hoop barns and by 5% for sows housed in individual stalls in confinement because of increased thermal demands. During lactation, sows received ad libitum access to a corn-soybean diet formulated for lactation (NRC, 1998). Individual feed intake during lactation was recorded.

Sows remained in the study until culling. Culling was done because of poor performance, failure to conceive by 70 d after weaning, lack of fitness (poor body condition, lameness), or death. Sows were not culled due to age or parity.

Statistical Analysis

Reproductive performance was summarized and analyzed for 957 litters. Data analysis showed that for litter-specific traits, the performance of sows that remained on the same gestation housing treatment for their entire productive lifetime after the first parity gestation did not differ from the performance of sows that changed housing treatments. Thus, all litter-specific data were analyzed considering each litter as the unit of analysis. The experimental unit was the individual sow, because the housing treatment was imposed on a particular sow at a particular parity.

Sow reproductive traits included numbers of pigs born alive, stillborn, total born, mummified, weaned, or nursed; litter weight at birth; litter weight at weaning; and weaning-to-breeding interval. The recorded traits were also used to calculate important indicators of productivity such as preweaning mortality and litter weight gain. Characteristics of sows recorded before and after lactation included breeding season (spring-summer: April to September or fall-winter: October to March), length of the previous lactation, and lactation length.

Litter-specific traits were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC). All models included the fixed effects of gestation housing, parity, and breeding season. Individual sow identity was included in all models as a random effect. The models for numbers born alive, stillborn, or mummified, and total pigs born also included the gestation housing × breeding

Table 2. Effects of gestation housing[1] and parity on reproductive performance of sows

Item	Stall	Hoop	SEM	*P*-value Trt	*P*-value Parity
No. of litters	552	405	—	—	—
Avg parity	4.4	4.6	0.1	0.30	—
No. born alive	9.3	10.0	0.2	0.002	<0.001
No. stillborn	2.0	1.7	0.1	0.055	<0.001
Total no. born	11.3	11.7	0.2	0.05	0.09
No. of mummified fetuses	0.21	0.25	0.04	0.28	0.76
Litter size after cross-fostering	10.5	10.4	0.1	0.70	0.50
Lactation length, d	18.8	18.8	0.5	0.98	0.001
Litter wt at birth, kg	16.2	16.3	0.2	0.44	<0.001
Preweaning mortality, %	14.0	15.0	1.0	0.72	0.001
Number weaned	8.9	8.8	0.1	0.48	0.001
Litter wt at weaning, kg	56.5	57.1	0.6	0.40	<0.001
Litter wt gain, kg	40.4	40.3	0.9	0.93	<0.001
Weaning-to-breeding interval, d	4.3	6.0	0.6	0.01	0.002

[1]Stall = individual gestation stalls in a confinement barn; Hoop = group pens in hoop barns with individual feeding stalls.

season interaction. The number born alive was included as a linear covariate in the model for litter weight at birth. The models describing pigs weaned and preweaning mortality included pigs nursed, lactation length, and litter weight at birth. The models for litter weight at weaning and litter weight gain also included lactation length and the number of pigs nursed. The number of pigs nursed after cross-fostering was described by a model that included the number of pigs born alive and lactation length. The weaning-to-breeding interval was analyzed using a model that included previous lactation length as a linear covariate.

Changes in sow BW and backfat during farrowing and lactation as well as feed consumption during lactation were examined using a mixed model that included the fixed effects of housing treatment, parity, and breeding season. Individual sow identification was included as a random effect. The combined effect of number of pigs nursed and length of lactation (number of pig days) was included in models of feed consumption during lactation and changes in sow BW and backfat due to farrowing and lactation.

Performing multiple hypotheses tests on the same data set increases the probability of declaring a particular test significant (SAS Institute, 2004). Reported means are least squares means and, when appropriate, differences between least squares means have been adjusted for multiple testing using the Tukey-Kramer method within SAS. The Tukey-Kramer method is a robust method of adjusting *P*-values to correct for multiple testing when addressing pairwise comparisons such as those in the current study (SAS Institute, 2004).

RESULTS

Reproductive performance data were recorded for 957 litters from 353 sows, and least squares means are summarized by housing treatment in Table 2. Sows housed in hoop barns during gestation gave birth to more ($P = 0.002$) live pigs per litter (10.0 ± 0.2) than sows gestated in confinement stalls (9.3 ± 0.2). There was a trend for sows kept in individual stalls to give birth to more stillborn pigs ($P = 0.06$), and sows gestated in hoops tended to give birth to more total pigs ($P = 0.05$). There were no differences ($P = 0.30$) in the number of mummified fetuses for the 2 housing treatments. Despite more pigs born alive, litters from sows gestated in groups were not heavier ($P = 0.40$) at birth or weaning than litters from sows gestated in individual stalls. Preweaning mortality was not different ($P = 0.70$) based on gestation housing. Due to cross-fostering across treatments to equalize litter size, number of pigs weaned per litter did not differ ($P = 0.50$) for the 2 gestation housing treatments. After weaning, sows that had been housed as individuals before farrowing successfully mated sooner ($P = 0.01$) than sows gestated in hoop barns. Parity affected all reproductive measures except total number of pigs born. There was no gestation housing treatment by parity interaction ($P \geq 0.10$) for any sow performance trait examined.

Least squares means for gestation housing treatment × breeding season interactions are detailed in Table 3. After Tukey-Kramer correction for multiple testing, interactions remained between gestation housing and breeding season. Sows bred during fall-winter (October to March) and gestated in hoop barns produced 10.3 live pigs/litter, which was more than the number of pigs born alive to sows bred during spring-summer (April to September) for either housing treatment ($P < 0.05$). Sows bred during the fall-winter and gestated in individual stalls gave birth to fewer ($P < 0.005$) live pigs (9.1 ± 0.2) than fall-winter-bred sows gestated in group pens in hoop barns (10.3 ± 0.3). Although the number born alive increased from the spring-summer to fall-winter breeding season for sows gestated in hoop barns, there was a trend for number born alive to decrease from the spring-summer to fall-winter breeding season for sows housed in confinement stalls. An identical pat-

Table 3. Effects of gestation housing and breeding season on reproductive performance of sows[1]

	Stall[2]			Hoop[2]		
Item	Spring-summer[3]	Fall-winter[4]	SE	Spring-summer[3]	Fall-winter[4]	SE
No. of litters	316	236		196	209	
No. born alive	9.5[ad]	9.1[bd]	0.2	9.7[ad]	10.3[ce]	0.3
No. stillborn	1.9[ad]	2.1[bd]	0.1	1.8[ad]	1.6[ce]	0.2

[a–c]Within a row, least squares means lacking a common superscript letter differ (Tukey-Kramer adjusted, $P < 0.05$).

[d,e]Within a row, least squares means lacking a common superscript letter differ (Tukey-Kramer adjusted, $P < 0.005$).

[1]Reproductive performance traits with a gestation housing × breeding season interaction.

[2]Stall = individual gestation stalls in a confinement barn; Hoop = group pens in hoop barns with individual feeding stalls.

[3]Spring-summer = April to September.

[4]Fall-winter = October to March.

tern was present for stillborn pigs. Sows that were bred during the fall-winter and then gestated in hoop barns gave birth to fewer ($P < 0.05$) stillborn pigs than spring-summer-bred sows housed in either housing treatment and fewer stillborn pigs ($P < 0.005$) than the fall-winter-bred sows gestated in confinement stalls.

Table 4 details sow BW and backfat characteristics as well as feed intake during lactation. Sows gestated in hoop barns weighed more before farrowing (P = 0.002) and at weaning (P = 0.004). Sows lost weight between entrance into the farrowing crate and weaning regardless of gestation housing treatment, and there was no difference between housing treatments on the amount of BW change (P = 0.20). Before farrowing and after lactation, sows gestated in hoop barns had slightly more backfat ($P < 0.001$). Sows housed in hoop barns for gestation lost slightly more backfat following farrowing and lactation (P = 0.003). Sow feed intake during lactation was not different (P = 0.40) for the 2 housing systems.

Table 4. Effects of gestation housing on BW, backfat depth, and lactation feed intake of sows[1]

Item	Stall	Hoop	SEM	P-value
No. of litters	516	387		
110-d wt,[2] kg	126.6	130.4	1.2	0.002
Wean wt, kg	114.1	116.8	1.0	0.004
Wt change, kg	–13.3	–14.4	0.5	0.19
110-d backfat depth,[2] mm	13.3	14.9	0.3	<0.001
Weaning backfat depth, mm	12.8	13.8	0.3	<0.001
Backfat change, mm	–0.6	–1.2	0.2	0.003
Lactation feed intake, kg	107.0	105.0	2.1	0.37
Lactation length, d	18.8	18.8	0.5	0.98

[1]Records for 36 sows housed in stall and 18 sows housed in hoop were incomplete due to maintenance of the scale or the Renco Lean Meter (Renco Corp., Minneapolis, MN) and were thus excluded from analysis. Stall = individual gestation stalls in a confinement barn; Hoop = group pens in hoop barns with individual feeding stalls.

[2]Initial weight and backfat were recorded when the sow was moved to the farrowing barn.

DISCUSSION

This study compared sow and litter performance in 2 distinct gestation housing systems. The multiple differences between the 2 systems make it difficult to conclusively explain observed production differences. Adoption of only 1 aspect of the hoop barn system is unlikely to result in similar effects on reproductive performance. Adoption of the entire system may result in improved reproductive performance due to the complementary effects of the multiple features of hoop barn gestation.

In the current study, sows gestated in hoop barns gave birth to more live pigs per litter. Equal preweaning mortality rates suggest that without the transfer of some pigs from sows gestated in hoop barns to sows gestated in individual stalls or to other litters not included in the study to equalize litter size within 24 h of birth, sows gestated in hoop barns may have weaned more pigs per sow. Number born alive generally increases over initial parities; reaches a peak at parity 3, 4, or 5; and then gradually declines over time (Clark and Leman, 1986; Whittemore, 1998). Sows in this study performed similarly (Figure 1). Figure 1 also details the number of sows assigned to each gestation treatment for a particular parity. In total, 58% of litters were born following gestation in individual stalls, whereas 42% of litters were born following gestation in hoop barns. A disproportionately greater number of litters from parity 3 through 5 sows were gestated in individual stalls. If the observed differences in number born alive could be explained entirely by parity differences, we would expect gestation in individual stalls to result in more live born pigs than gestation in hoop barns. This is the opposite of what was found, supporting the argument that the difference in number born alive between the 2 gestation systems is not simply the result of the influence of sow parity. There was no gestation housing treatment × parity interaction ($P \geq 0.10$) for any trait examined, including number of live born pigs.

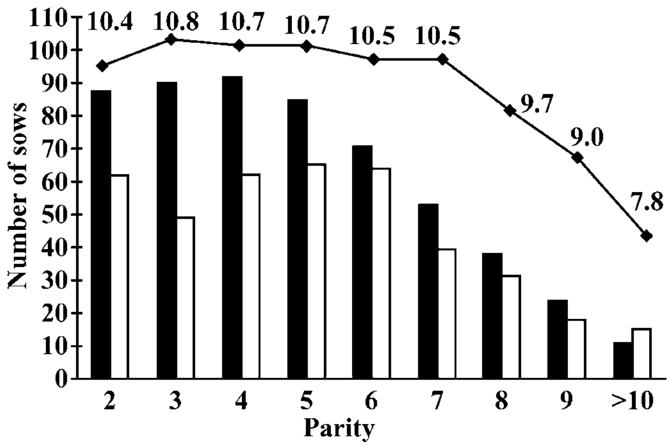

Figure 1. Number of litters farrowed and live pigs born per litter by sow parity; black bars = litters from sows gestated in an individual gestation stall in a confinement barn; white bars = litters from sows gestated in group pens in a hoop barn with individual feeding stalls; —◆— = number of live-born pigs per litter (numbers above the line indicate the least squares mean).

Sows in hoop barns were confronted with a more variable thermal environment, and daily feed allowance was increased to account for higher-energy demand for thermal regulation. Previous workers have shown that increasing feed allowance during gestation did not affect number of pigs born (Michel and Easter, 1985). If basal diets are sufficient, increasing the energy content of the gestation diet does not influence the number of live born pigs (Hoppe et al., 1990; Coffey et al., 1994; Matte et al., 1994).

In the current study, there was a trend for individually housed sows to give birth to more stillborn pigs ($P = 0.06$). Sows kept in confinement stalls gave birth to fewer live pigs ($P = 0.002$) but equal numbers of total pigs ($P = 0.05$), suggesting that they may have been less able to successfully deliver their pigs alive. Increasing the length of parturition increases the extent of neonatal asphyxia, the leading cause of noninfectious stillbirth (Herpin et al., 1996). Although not all pigs experiencing asphyxia perish, prolonged or intermittent lack of O_2 during delivery reduces the ability of the newborn pig to adapt to extrauterine life (English and Wilkison, 1982; Herpin et al., 1996). Uterine and overall muscle tone influences length of parturition (English and Wilkison, 1982). A possible reduction of muscle tone, perhaps from lack of exercise in the sows housed as individuals, may explain the difference in number of live pigs born from the 2 gestation systems.

Sows gestated in hoop barns had exposure to bedding for most of gestation. Sows housed in individual gestation stalls did not. The presence of bedding and the ability to huddle together or maintain distance among animals may have enabled the sows gestated in hoop barns to have more control over their thermal environment. The different effects of breeding season on number of pigs born alive and stillborn pigs for the 2 gestation housing treatments may in part be explained by the enhanced ability of sows gestated in hoop barns to modify their thermal environment.

Sows housed in individual stalls had a shorter weaning-to-breeding interval ($P = 0.01$) compared with sows gestated in hoop barns. A reduced weaning-to-breeding interval may result in a sow farrowing more litters of pigs per year. Sows in individual stalls that returned to estrus after service were easily identified and rebred. Detecting sows in estrus within groups kept in hoop barns, rebreeding those animals, and incorporating them into another gestation group in hoop barns proved more difficult due to a limited number of group gestation cohorts and pens in hoop barns on the farm. This resulted in a small number of animals kept in hoop barns displaying very long weaning-to-breeding intervals. It is likely that in a commercial setting using group housing in hoop barns, an increased number of barns and gestation cohorts would enable more timely reintroduction of a sow that failed to conceive or lost her pigs midpregnancy into the gestating herd. Additionally, the sow manager would probably only be managing 1 gestation housing system and not 2 systems, as in this study.

The labor and skill sets needed for successful management of sows housed in groups may be different from those needed to manage individual gestation stalls. Group housing systems do not require more labor per animal than individual gestation stalls (Backus et al., 1997) and in some cases may require less (den Hartog et al., 1993; Bates et al., 2003). Systems with individual gestation stalls in mechanically ventilated confinement buildings are the result of decades of experience and refinement. In the United States, using a bedded system for keeping gestating sows such as hoop barns is a relatively unfamiliar management strategy. Despite being a relatively novel management strategy in the United States, results of this study show that gestating sows can be housed in deep-bedded hoop barns equipped with individual feed stalls and perform comparably to gestating sows housed in confinement buildings with individual gestation stalls. With increased experience, management and technique will evolve and production may be enhanced.

LITERATURE CITED

Backus, G. B. C., H. M. Vermeer, P. F. M. M. Roelofs, P. C. Vesseur, J. H. A. N. Adams, G. P. Binnendijk, J. J. J. Smeets. C. M. C. van der Peet-Schwering, and F. J. van der Wilt. 1997. Comparative study of four housing systems for non-lactating sows. Pages 273–279 in 5th Int. Livest. Environ. Symp., Bloomington, MN. ASAE, St. Joseph, MI.

Barbari, M. 2000. Analysis of reproductive performance of sows in relation to housing systems. Pages 188–196 in Swine Housing. Proc. 1st Int. Conf., Des Moines, IA. ASAE, St. Joseph, MI.

Barnett, J. L., P. H. Hemsworth, G. M. Cronin, E. C. Jongman, and G. D. Hutson. 2001. A review of the welfare issues for sows and piglets in relation to housing. Aust. J. Agric. Res. 52:1–28.

Bates, R. O., D. B. Edwards, and R. L. Korthals. 2003. Sow performance when housed either in groups with electronic sow feeders or stalls. Livest. Prod. Sci. 79:29–35.

Clark, J. R., and A. D. Leman. 1986. Factors that influence litter size in pigs: Part 1. Pig News Info. 7:303–310.

Coffey, M. T., B. G. Diggs, D. L. Handlin, D. A. Knabe, C. V. Maxwell Jr., P. R. Noland, T. J. Prince, and G. L. Cromwell. 1994. Effects of dietary energy during gestation and lactation on reproductive performance of sows: A cooperative study. J. Anim. Sci. 72:4–9.

Connnor, M. L., D. L. Fulawka, and L. Onishuk. 1997. Alternative low-cost housing for pregnant sows. Pages 393–399 in 5th Int. Livest. Environ. Symp., Bloomington, MN. ASAE, St. Joseph, MI.

den Hartog, L. A., G. B. Backus, and H. M. Vermeer. 1993. Evaluation of housing systems for sows. J. Anim. Sci. 71:1339–1344.

England, D. C., and D. T. Spurr. 1969. Litter size of swine confined during gestation. J. Anim. Sci. 28:220–223.

English, P. R., and V. Wilkison. 1982. Management of the sow and litter in late pregnancy and lactation in relation to piglet survival and growth. Pages 479–506 in Control of Pig Reproduction. D. J. A. Cole and G. R. Foxcroft, ed. Butterworth Sci., Essex, UK.

European Union. 2001. Council directive 2001/88/EC amending directive 91/630/EEC laying down minimum standards for the protection of pigs. Official. J. Eur. Community L 316:1–4.

Harmon, J. D., M. S. Honeyman, J. B. Kliebenstein, T. Richard, and J. M. Zulovich. 2004. Hoop Barns for Gestating Swine. AED 44. MidWest Plan Service, Ames, IA.

Herpin, P., J. Le Dividich, J. C. Hulin, M. Fillaut, F. De Marco, and R. Bertin. 1996. Effects of the level of asphyxia during delivery on viability at birth and early postnatal vitality of newborn pigs. J. Anim. Sci. 74:2067–2075.

Honeyman, M. S., and J. D. Harmon. 2003. Performance of finishing pigs in hoop structures and confinement during winter and summer. J. Anim. Sci. 81:1663–1670.

Honeyman, M. S., J. D. Harmon, J. B. Kliebenstein, and T. L. Richard. 2001. Feasibility of hoop structures for market swine in Iowa: Pig performance, pig environment, and budget analysis. Appl. Agric. Eng. 17:869–874.

Hoppe, M. K., G. W. Libal, and R. C. Wahlstrom. 1990. Influence of gestation energy level on the production of Large White × Landrace sows. J. Anim. Sci. 68:2235–2242.

Jensen, P., and D. G. M. Wood-Gush. 1984. Social interactions in a group of free-ranging sows. Appl. Anim. Behav. Sci. 12:327–337.

Matte, J. J., S. Robert, C. L. Girard, C. Farmer, and G.-P. Martineau. 1994. Effect of bulky diets based on wheat bran or oat hulls on reproductive performance of sows during their first two parities. J. Anim. Sci. 72:1754–1760.

Mesonet. 2005. Iowa environmental mesonet climodat reports. http://mesonet.agron.iastate.edu/climodat/ Accessed Oct. 2005.

Michel, E. J., and R. A. Easter. 1985. Reproductive performance of first and second parity sows fed daily or every third day. Livest. Prod. Sci. 13:179–189.

Morris, J. R., J. F. Hurnik, R. M. Friendship, and N. M. Evans. 1998. The effect of the Hurnik-Morris (HM) system on sow reproduction, attrition, and longevity. J. Anim. Sci. 76:2759–2762.

Moynagh, J. 2000. EU regulations and consumer demand for animal welfare. AgBioForum 3:107–114.

NRC. 1998. Nutrient Requirements of Swine. 10th rev. ed. Natl. Acad. Press, Washington, DC.

SAS Institute. 2004. SAS/Stat 9.1 User's Guide. SAS Inst. Inc., Cary, NC.

Snelson, H. 2005. Arizona initiative to ban veal and sow stalls. http://www.aasv.org/news/story.php?id=1690 Accessed Jan. 2006.

Stolba, A., and D. G. M. Wood-Gush. 1989. The behavior of pigs in a seminatural environment. Anim. Prod. 48:419–425.

Svendsen, J., and L. S. Svendsen. 1997. Intensive (commercial) systems for breeding sows and piglets to weaning. Livest. Prod. Sci. 49:165–179.

USDA. 2001. Part 1: Reference of swine health and management in the United States, 2000. N338.0801. Natl. Anim. Health Monit. Syst., Fort Collins, CO.

Whittemore, C. T. 1998. The Science and Practice of Pig Production. 2nd ed. Univ. Press, Cambridge, UK.