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Fender design and insulation of farrowing huts: Effects on performance of outdoor sows and piglets¹

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ABSTRACT: Two studies assessed sow and litter performance when design features of farrowing huts varied. A fender is a structure that extends out the front of the hut to create a veranda that prevents young piglets from leaving. In Exp. 1, 206 lactating sows and their litters were used to assess litter performance and the time required to process litters for two fender designs (short wooden [WS] vs. tall metal with a board front [MT-b]) and insulation status (insulated [IN] vs. uninsulated [UN]) farrowing huts. A significant fender \times insulation interaction was observed for total litter weaning weight. Lighter litters weaned ($P = 0.013$) from WS fenders with UN huts compared with the other treatments. Fender design did not ($P > 0.05$) influence the time required to process a litter with one stockper-

son. Less total time ($P = 0.001$) was required to process a litter when two people were present (10.60 ± 0.74 min) compared with one stockperson (14.52 ± 0.74 min). There were no ($P > 0.05$) differences between IN and UN huts for temperature and relative humidity measurements. In Exp. 2, 331 lactating sows and their litters were used to determine sow and litter performance when using one of two fender front designs (boards [MT-b] vs. roller [MT-r]). The front design of the fender did not influence ($P > 0.05$) most litter performance measures. We conclude that fender design, fender fronts, and insulation effects did not have large influences on sow and litter performance in a West Texas environment.

Key Words: Design, Farrowing House, Insulation, Performance, Piglets, Sows

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Introduction

Several farrowing hut designs are currently in commercial use with varying performance success (Honeyman et al., 1998a). Research has focused on the shape of the hut (McGlone and Hicks, 2000) and the space requirement needs of the sow (Curtis, 1988; Honeyman et al., 1998b). However, directly comparing fender designs (Honeyman et al., 1998a; Frampton et al., 2000) and potential benefits of insulating farrowing huts (Edwards et al., 1994; 1995) has rarely been studied with the aims of optimizing sow and litter performance.

Fenders are partitions that are fixed onto the front of the farrowing hut, which allows the sow unrestricted access to the farrowing hut and paddock, but restricts young piglets to the farrowing hut and fender area (Honeyman et al., 1998c). The first style of fender is a low wooden structure and the second is a taller, metal structure. The taller metal fenders can have two types of front, wooden boards or a plastic polyvinyl chloride (PVC) roller. Fender design may influence the length of time that piglets are confined to the hut and the work efficiency for the stockperson carrying out routine tasks (i.e., litter processing). Furthermore, insulating farrowing huts may help to reduce diurnal temperature fluctuations, which may benefit piglet survival and overall performance (Edwards et al., 1995).

The aims of these studies were to compare the performance of sows and piglets in an outdoor farrowing hut with two fender designs (short wooden or tall metal), two fender front designs (roller or board) and two insulation statuses (insulated and uninsulated). Finally, we assessed the time needed for one or two stockpersons to process a litter with either a short wooden or a tall metal fender.

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Table 1. Weather measurements for the Sustainable Pork Farm, Lubbock, TX from July to November 1999 (Exp. 1) and from July to December 2000 (Exp. 2)

| Climatic measurement | 1999 | | | | | 2000 | | | | | |
|---------------------------|------|------|------|------|------|------|------|------|------|------|------------------|
| | Jul | Aug | Sept | Oct | Nov | Jul | Aug | Sept | Oct | Nov | Dec ^a |
| Air temperature, °C | | | | | | | | | | | |
| Minimum ^b | 18.8 | 18.8 | 14.7 | 6.4 | 2.6 | 18.9 | 17 | 13.3 | 10.7 | 0 | -4 |
| Maximum ^c | 36.8 | 40.4 | 31.1 | 26.4 | 13.6 | 37.1 | 38.1 | 34.7 | 23.9 | 13.3 | 10.3 |
| Average air temperature | 27.3 | 28.2 | 21.4 | 15.5 | 11.9 | 27.2 | 27.1 | 23.5 | 16.3 | 5.5 | 2.2 |
| Relative humidity, % | | | | | | | | | | | |
| Minimum ^d | 26.9 | 21.5 | 34.9 | 26.4 | 24.8 | 28.3 | 24.4 | 20.5 | 45.5 | 43.4 | 52.8 |
| Maximum ^e | 79.9 | 75.5 | 84.2 | 82.3 | 75.2 | 81.2 | 70.2 | 63.6 | 87.1 | 89.2 | 83.8 |
| Average relative humidity | 51.7 | 47.3 | 59.7 | 55.5 | 50.1 | 53.9 | 44.3 | 39.2 | 68.2 | 68.7 | 68.5 |
| Total precipitation, cm | 1 | 4.4 | 3.4 | 2.4 | 0 | 0 | 0.2 | 0.1 | 5.7 | 14.4 | 23.2 |
| Wind velocity, km/h | 28.5 | 22.3 | 29.6 | 30.9 | 15.9 | 27.7 | 23.5 | 28.9 | 33.8 | 30.1 | 31.7 |

^aIn December 2000, the weather station stopped working on December 26, 2001, due to an ice storm, and snow and rain were not recorded completely; however, Lubbock County had 23.16 cm of precipitation (National Weather Service, 2000).

^bAverage minimal temperatures, °C.

^cAverage maximal temperatures, °C.

^dAverage minimal relative humidity, %.

^eAverage maximal relative humidity, %.

Materials and Methods

General

Breeding-age gilts (Camborough-22, PIC USA, Franklin, KY) were obtained from a single source farm and were considered to have a high health status (negative for pseudorabies, brucellosis, porcine respiratory and reproductive virus syndrome, and mycoplasmal hyopneumonia). Research was conducted at the Sustainable Pork Farm situated in an area with a dry steppe climate producing mild winter temperatures near Lubbock, Texas. Average weather data during each study are given in Table 1.

Diets, Housing, and Husbandry

Sows remained outdoors during breeding, gestation, and farrowing. Animals were housed and used in accordance with the Guide for the Care and Use of Agricultural Animals Used in Agricultural Research and Teaching (FASS, 1999) and the project was approved by the Texas Tech University Animal Care and Use Committee.

All sows were artificially inseminated and pregnancy checked 4 wk later using real-time ultrasound. Pregnant sows were then moved into a gestation paddock. Sows for both experiments were gestated in 16 groups of 24 sows per group per gestation paddock. Within these gestation groups sows were of mixed parity and were kept in the same social group through both the gestation and farrowing phases.

Five days prior to scheduled farrowing, gestation sows were transferred to the farrowing paddock. In farrowing, this larger gestation group was split into three smaller farrowing groups containing eight sows per group per farrowing paddock. Each farrowing paddock was 0.4 ha. Single-stranded electrical wire (12

A) surrounded each farrowing paddock, which was 59 cm above the ground.

In each paddock, English-style arc farrowing huts (1.12 m × 2.79 m × 1.65 m) were used to house one sow and her litter (McGlone and Hicks, 2000). One door was to the left side of each farrowing hut (1.23 m × 1.18 m), and a ventilation window was positioned on the back wall (43 cm × 1.19 m). The ventilation window was occasionally closed at the discretion of the farrowing manager. This was achieved by placing a wooden board (51 cm × 1.19 m) over the open window. Closure rate was the same between insulated and uninsulated huts. All farrowing huts were orientated south. Short chopped wheat straw was used for bedding.

Sows were fed once daily at 0800 a completely balanced sorghum based diet, (CP 16%; 1,535 kcal of ME/kg; lysine 0.95%) in a designated strip area along one side of the perimeter fence. Depending on the stage of lactation, sows were fed the appropriate amount of feed (2 to 9 kg/d; NRC, 1998). Sows had unrestricted access to clean drinking water and a wallow was available for thermoregulation. Piglets were not provided with creep feed, but did have access to ground cover. Predominate ground cover throughout the year was WW-Spar blue (*Bothriochloa ischaemum*), which was planted on site. Every sow and her litter were checked twice daily for health, dead piglets, or farrowing problems. Each day, new straw was provided to the litters that were 10 d of age or less. For older litters, straw was added twice weekly or as required. Fenders were attached after the sow had chosen her farrowing hut and prior to piglets being born.

Performance Measurements

In both experiments, piglets were counted and weighed at birth and weaning. Total piglets per litter

was divided further into piglets born alive, mummies, and stillborns. Mummies were classified as such if they had one or more of the following characteristics: rubbery skeleton, bloated stomach, lack of hair, brown to black body color, sunken eyes, loose skin, or bad odor. Stillborns were recorded as any piglet found dead during or shortly after farrowing that had not breathed. Prewaning mortality was defined as any piglet that was born alive but died before weaning. Causes of death were mainly crushing of the piglet by the sow and starvation categorized by the stockperson through internal and external examination of the heart, lungs, stomach, and skin. Processed piglets that did not die before weaning but were not weaned were classified as missing. Sows were weighed on the day that she entered the farrowing facilities and on the day she returned to breeding.

Experiment 1

Experiment 1 was conducted from July to November 1999. A total of 206 lactating sows, and their litters were used over their first ($n = 45$) and second ($n = 161$) parities. The difference between the numbers of sows in their first and second parity can be attributed to the breeding schedule of the farm. Most of the gilts had previously farrowed in March 1999 and this experiment did not begin until July 1999. Data collection ceased in November 1999 because an additional experiment was being conducted in the farrowing pasture. Concern was raised over the possibility of an effect in the second trial on sow and litter performance, and therefore, data after November 1999 were not included for this study.

Fender and Insulation Material

Two main fender designs are used commercially in our region. The first is a low wooden structure and the second is a taller, metal structure. Exp. 1 either had a short wooden (WS) fender, ($0.30 \text{ m} \times 1.20 \text{ m} \times 1.20 \text{ m}$) or a tall metal (MT) fender ($0.9 \text{ m} \times 2.7 \text{ m}$ width at the back of the hut and 0.7 m at the front $\times 1.60 \text{ m}$ length; Figure 1). MT-b fenders had one wooden board ($0.12 \text{ m} \times 0.03 \text{ m} \times 0.78 \text{ m}$) that slotted in the front portion of the fender (Figure 1, picture 2). The board combined with the base of the fender made a total height of 0.3 m . The side meshing on the metal fenders was made from hot dipped galvanized steel and two black iron rods (1.27 cm diameter) attached the fender to the farrowing hut. Half of the farrowing huts were insulated (IN) with instant foam polyurethane rigid roofing spray foam, which was applied at a thickness of 1.80 cm on the sides of the hut and 3.8 cm on the roof (Flexible Products Co., GA). The remaining farrowing huts were classified as uninsulated (UN). Insulation that was removed around the base of the farrowing hut was not repaired between batches due to additional expense.



Figure 1. Three pictures depicting the fender designs and fronts. For Exp. 1, a short wooden fender (WS; picture 1) was compared to a tall metal fender with a board (MT-b; picture 2). In Exp. 2, fender fronts for tall metal (MT) fenders were compared, a board ([MT-b]; picture 2) front with a roller ([MT-r]; picture 3) front.

Farrowing huts in both Exp. 1 and 2 were used multiple times over the duration of each study. On the day of weaning farrowing huts and fenders were moved to a new farrowing paddock. Within the new farrowing paddock, hut location was re-randomized. Within each farrowing paddock every combination of fender design and insulation status was present and replicated accordingly.

A fender was removed when half of the piglets in that litter had cleared the fender on their own. Average removal time per fender was not recorded in this study.

Performance

One hundred eleven replications per treatment for WS fenders and 95 replications per treatment for MT-b fenders were used for performance measures. The study involved 104 replications per treatment for insulated huts and 102 replications per treatment for uninsulated huts. Farrowing pastures had equal numbers of WS and MT-b fenders attached to IN and UN farrowing huts for all batches of sows respectively. The approximate weaning age for piglets on this study was 25 d.

Management and Hut Climatic Measurements

Over a 10-wk period, eight litters were processed weekly for farrowing hut ergonomic evaluation of the time required to process a litter. These litters were processed at an average age of 3 d. Treatments consisted of 1) one stockperson processing a litter at either a WS ($n = 20$) or a MT-b ($n = 20$) fender and 2) two stockpersons processing a litter with either a WS ($n = 20$) or a MT-b ($n = 20$) fender. Timing began when the stockpersons had positioned the tractor and trailer at the farrowing hut door (once the WS fender had been detached) or to the MT-b fender opening. The WS fender was detached so that the trailer could back right up to the door. This then facilitated that stockperson to move the sow out of the hut straight onto the trailer. Timing stopped once all piglets had been processed and were returned to their farrowing hut with the sow inside.

On the day of processing, sows in the designated farrowing paddock were not fed at first with the remaining farrowing paddocks. The stockperson loaded one sow at a time onto the trailer and locked the back gate for stockperson safety. Each sow on the trailer was given a small amount of lactation feed (about 4 kg). Each piglet from the confined sow was collected by hand and put into a wheat straw-lined plastic basket ($0.34 \text{ m} \times 0.52 \text{ m} \times 0.66 \text{ m}$) for processing. The task of processing was conducted outside of the farrowing paddock to prevent the dam or other sows from becoming agitated. Processing included tail docking, ear notching, castration, and weighing each piglet by placing individual piglets into a bucket attached to a scale

(Handy Bonso, Florham Park, NJ). Piglets were returned to their farrowing hut through the back window. Finally the sow was released from the trailer and returned to her hut and litter. This was repeated for all individual sows and litters that were designated for processing. Once the pasture had been processed, all sows were provided with their remaining feed ration.

Processing time included travel from the farrowing hut to the processing area outside of the paddock and back to the farrowing hut. To prevent inherent bias of treatments, the farrowing paddock was randomized weekly in placement of farrowing hut/stockperson combinations.

Hut climatic measurements were recorded with eight data loggers (Hobo Pro series, Janesville, WI). Hobos were affixed inside the farrowing huts (30 cm away from the door opening and 1.12 m from ground level). Ambient temperature and relative humidity (RH) were recorded in 15-min intervals. Four data loggers were placed inside IN farrowing huts and four inside UN farrowing huts. Environmental temperatures were recorded by a weather station (Weather monitor II, model 7440 Davis Instruments, Baltimore, MD) located on site. Weather measurements taken were outdoor temperature in degrees Celsius, percentage RH, wind speed (km/h), and precipitation (cm). Measurements were recorded at 30-min intervals. Daily weather measurements were averaged for each month of the study.

Experiment 2

Experiment 2 was conducted from July to December 2000. A total of 331 lactating sows and their litters were used over five parities: parity one ($n = 57$), two ($n = 54$), three ($n = 53$), four ($n = 112$), and five ($n = 55$). The same farm was used as that described for Exp. 1.

Sixty tall metal fenders (as described in Exp. 1) were fixed onto all the farrowing huts. Thirty farrowing huts were assigned a front board (MT-b), while the remaining 30 had a PVC (MT-r) roller (0.12 m height, 0.12 m radius, and 0.64 m length; Figure 1, picture 3). To prevent the sow from using her snout to lift either the roller or boards out of the fender, a metal clip was inserted on each side through a predrilled hole on the front panel of the fender doorway. One hundred sixty-four replications per treatment for boards and 167 replications per treatment for rollers were used for performance measures. The fender type (MT) and performance measures collected were as described for Exp. 1. The weaning age for piglets on this study was 21.6 ± 0.84 days for piglets housed with a MT-b front and 22.5 ± 0.86 d for piglets housed with a MT-r.

The decision to remove a fender was when half of the piglets in that litter had cleared the fender. Average

removal time per fender was not recorded in this study.

Statistical Analysis

Analyses were performed using the GLM procedure in SAS (SAS Inst., Inc., Cary, NC) software for parametric data. The experimental unit was the farrowing hut for both experiments (containing one sow with her litter).

A randomized complete block design with a split plot (over parity) was used to analyze performance data for Exp. 1. The block was the weaning week ($n = 21$ wk) and the block nested within fender by insulation was the error term. The statistical model main plot included fender design (WS and MT-b) and insulation status (IN or UN). The subplot included, parity, parity \times fender design, parity \times insulation status, and parity \times fender design \times insulation status. One covariate, the total number of piglets born per litter, was included in the model for weaning weight data.

A completely randomized design was used to analyze litter-processing times for Exp. 1. Three covariates—the number of piglets to be processed, the age of the piglets, and the total litter birth weight—were included in the model.

A randomized block, split plot design was used to analyze climatic data for Exp. 1. The block was the month ($n = 4$) and block \times insulation status was the error term. The statistical model main plot included insulation status (IN vs. UN). The subplot included time of day and insulation status \times time of day. Hobo device within treatment \times time interaction was the error term for time of day and treatment \times time.

A randomized block design was used to analyze performance data for Exp. 2. The block was the weaning week ($n = 24$ wk) and the treatment by block was the error term. One covariate, sow parity, was included in the model.

Results

Experiment 1—Performance

There were no performance differences ($P > 0.05$) between WS and MT-b fenders or insulation (UN vs. IN) status for number of piglets born alive/litter, stillbirths, number of piglets weaned/litter, litter birth and weaning weights, piglet mortality, missing piglets, or the sow starting and ending weights and weight differences (Table 2). No piglets born were classified as mummies. There was a fender \times insulation interaction for litter weaning weight/litter (Figure 2; $P = 0.013$). Lighter litters were weaned from WS fenders with UN huts compared with the other treatments. There were no ($P > 0.05$) other fender \times insulation interactions for the remaining performance measures. There was a parity by fender \times insulation interaction with parity 1 sows having a higher ($P = 0.019$) inci-

dence of stillborns for MT-b with IN huts compared with MT-b with UN and WS with IN (Figure 3). There were no other significant ($P > 0.05$) treatment or interaction effects.

Ergonomics of Litter Processing

The design of the fender did not differ in the time required for one stockperson to process a litter. WS fenders required 11.7 ± 0.74 min and MT-b fenders required 13.4 ± 0.74 min to process litters ($P = 0.10$). Less total time ($P = 0.001$) was required to process a litter (averaged over fender type) when two people were present (10.6 ± 0.74 min) compared with one stockperson (14.5 ± 0.74 min). The fender design (WS vs. MT-b) \times number of stockperson interaction was not significant ($P > 0.10$). In terms of total personnel time, one stock person required less time (about 15 min) to process a litter than when two people processed a litter (about 21 person min).

Climatic Measurements

Temperatures were warm during this study, with moderate to low RH (Figure 4). There were no differences ($P > 0.05$) in average daily temperature inside IN ($21.1 \pm 1.17^\circ\text{C}$) or UN ($24.5 \pm 1.29^\circ\text{C}$) farrowing huts and no differences for RH ($P = 0.30$) inside IN ($44.2 \pm 1.49\%$) or UN ($46.7 \pm 1.61\%$) farrowing huts. Insulation changed the time of heating and cooling within the hut, but not the average inside air temperature. There were also no treatment \times time interactions ($P > 0.10$) for temperature or RH.

Experiment 2

Presented in Table 3 are least squares means for Exp. 2. The front design of the fender (board vs. roller) did not affect ($P > 0.05$) the number of piglets born/litter, stillbirths, number of piglets born alive/litter, number of piglets weaned/litter, litter birth and weaning weights, piglet mortality, and missing piglets. No piglets born were classified as mummies. There were no ($P = 0.24$) differences in sow starting weights between sows that had boards (262.6 ± 2.80 kg) compared with rollers (256.7 ± 2.81 kg) or ending weights ($P = 0.17$; 237.2 ± 3.17 vs. 240.2 ± 3.0 kg) for board vs. roller, respectively. Therefore, overall weight loss was similar ($P = 0.40$) for sows with boards (-20.2 ± 2.23 kg) compared with sows with rollers (-20.6 ± 2.14 kg).

Discussion

Performance

Few studies have compared fender use on sow and litter performance (Honeyman et al., 1998c; Frampton et al., 2000). However, concern has been expressed over the mother-offspring bond when fenders are used in alternative farrowing systems (Bøe 1993; 1994).

Table 2. Least squares means and standard errors for main effects of fender design (short wooden [WS] vs. tall metal [MT-b]) and insulation status (insulated vs. noninsulated) for the performance of sows and their litters from Exp. 1^a

| Measure | Fender Design | | Insulation | | P-values | |
|--|---------------|--------------|--------------|--------------|----------|-----------|
| | Short wooden | Tall metal | Insulated | Uninsulated | Fender | Insulated |
| Number of sows and litters | 111 | 95 | 104 | 102 | | |
| Piglets born alive No./litter | 10.6 ± 0.45 | 10 ± 0.47 | 10.5 ± 0.52 | 10.1 ± 0.39 | 0.43 | 0.63 |
| Stillbirths | 0.7 ± 0.22 | 1.3 ± 0.23 | 1.1 ± 0.25 | 0.9 ± 0.19 | 0.06 | 0.52 |
| Litter birth weight, kg | 19.1 ± 1.10 | 16.6 ± 1.17 | 18.5 ± 1.27 | 19.2 ± 0.99 | 0.78 | 0.68 |
| Avg. piglet birth weight, kg | 1.9 ± 0.15 | 2 ± 0.15 | 1.9 ± 0.17 | 1.9 ± 0.13 | 0.55 | 0.73 |
| Piglet mortality, No./litter | 2.2 ± 0.44 | 2.2 ± 0.46 | 2.1 ± 0.50 | 2.3 ± 0.38 | 0.97 | 0.77 |
| Mortality, % | 20.2 ± 5.68 | 19.6 ± 5.99 | 17.9 ± 6.59 | 21.8 ± 4.99 | 0.94 | 0.65 |
| Days of lactation | 25.8 ± 1.09 | 24.7 ± 0.44 | 24.7 ± 0.95 | 25.9 ± 0.86 | 0.36 | 0.45 |
| Piglets weaned, No./litter | 8.3 ± 0.47 | 7.7 ± 0.50 | 8.2 ± 0.54 | 7.7 ± 0.41 | 0.41 | 0.49 |
| Litter wean weight, kg | 60.6 ± 4.55 | 58.3 ± 5.13 | 59.9 ± 5.66 | 58.9 ± 3.87 | 0.74 | 0.89 |
| Avg. piglet wean weight, kg | 7.1 ± 0.43 | 7.4 ± 0.39 | 7.4 ± 0.43 | 7.1 ± 0.29 | 0.58 | 0.55 |
| Number of missing piglets ^b | 0.4 ± 0.22 | 0.3 ± 0.24 | 0.4 ± 0.27 | 0.3 ± 0.20 | 0.96 | 0.68 |
| Sow start weight, kg ^c | 253.8 ± 7.81 | 264.2 ± 6.22 | 262.9 ± 6.98 | 254.9 ± 7.14 | 0.30 | 0.43 |
| Sow end weight, kg ^c | 231.3 ± 8.05 | 245.7 ± 6.85 | 244.3 ± 7.79 | 232.6 ± 7.14 | 0.18 | 0.27 |
| Sow weight difference, kg ^c | -22.1 ± -9.16 | -22.6 ± 9.06 | -25 ± 8.67 | -19.7 ± 9.53 | 0.97 | 0.68 |

^aBlock nested within fender × insulation was used as the error term, and the total number of piglets born/litter was used as the covariate.

^bMissing piglets due to predation, piglet wandering off, and unknown causes.

^cWeight of sow on the day she entered the farrowing facilities and on the day she returned to breeding after piglets were weaned. Weight difference was calculated from start weight minus end weight.

Marchant et al., (2000) studied a free crate system. This design consisted of a farrowing pen for the piglets and a communal area for sows. Piglets were confined to the farrowing pen by a roller at the door of the pen. Sows could spend increasing percentages of their time budget lying in the communal area, returning to the home pen to nurse. While all the piglets in a litter remained confined to the home pen, this system caused few problems. However, if some piglets managed to escape from the home pen while the roller was still in place, the sows had the option of nursing piglets in the communal area without returning to the home pen. The authors suggested that this may have been one reason for the larger numbers of piglets remaining in the home pen dying from starvation and hypothermia between d 2 and 6 postpartum. Frampton et al.,

(2000) reported that lighter piglets were weaned from sows that had a roller fixed in the doorway vs. doorways with no roller and reached a similar conclusion to the previous study that lighter litters may have been due to the sow having control over her nursing frequency. In contradiction to these studies, Honeyman et al. (1998c) compared farrowing huts with either a wooden fender or a doorway partition and concluded that there were no performance differences between the two designs. Numerous studies on the feral sow have indicated weaning as a gradual process over a 12-wk period and that sows returned to the nest area frequently to suckle their young over the first 10 d of age (Newberry and Wood-Gush 1985; Jensen and Recén 1989; Jensen et al., 1991). In agreement

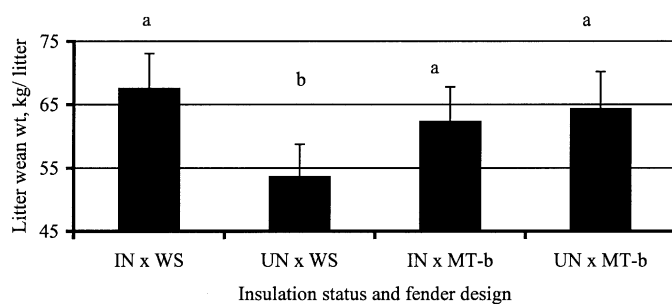


Figure 2. Litter weaning weight, kg/litter for Parity 1 and 2 sows from Exp. 1. The WS were the short wooden fenders and MT-b the tall metal fenders. The IN were the insulated and UN the uninsulated English-style farrowing arcs. Least squares means with a different letter (a, b) differ (fender × insulation $P = 0.013$; $n = 206$ litters).

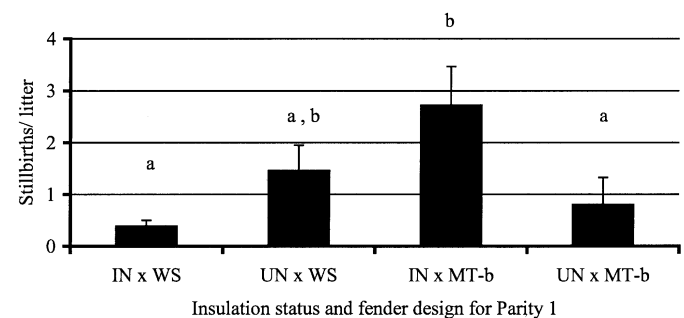


Figure 3. Number of piglets stillborn/litter for Parity 1 sows from Exp. 1. The WS were the short wooden fenders and MT-b the tall metal fenders. The IN were the insulated and UN the uninsulated English-style farrowing arcs. Least squares means with a different letter (a, b) differ (fender × insulation $P = 0.019$; $n = 206$ litters).

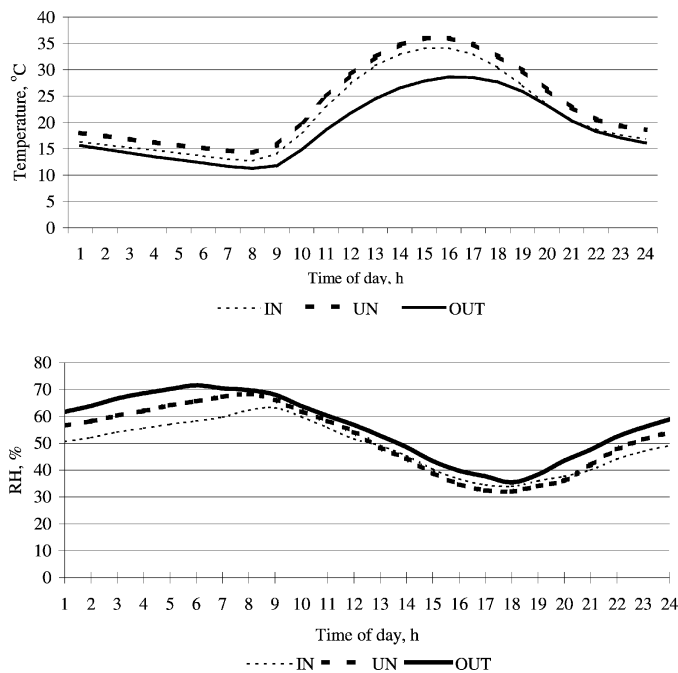


Figure 4. Average temperature (SEM = 1.23°C) and relative humidity (SEM = 1.5%) inside four insulated and four uninsulated farrowing huts, with outside temperature and relative humidity for comparison. IN = insulated hut, UN = uninsulated hut, OUT = outside air temperature, RH = relative humidity.

with the feral sow observations, Arey and Sancha (1996) reported that the majority of sows in family systems only began nursing frequently in the communal area once piglets were 10 to 14 d of age and had cleared the barrier. Therefore, the role of the fender might be to confine young piglets to the nest area, but once the majority of the litter is able to jump or climb over the fender it should be removed, allowing the litter to follow their mother and frequently nurse until weaning. In our study we removed the fender once half of a litter were out on pasture and this caused no performance differences between the two fender designs.

Although fender design and insulation effects separately did not result in performance effects, a combination may be important. In Exp. 1, insulated farrowing huts that had a short wooden fender (WS) attached weaned a lighter litter (53.6 kg) compared with other combinations (about 64 kg). Almost certainly sows in uninsulated farrowing huts with short wooden fenders produced less milk and weaned lighter litters; however, numerous factors have been related to milking performance of the sow, such as the nursing frequency (Jensen et al., 1991; Spinka et al., 1997), thermal environment (Fuquay, 1981; Quiniou and Noblet, 1999), water intake (Fraser and Phillips, 1989), and sow and piglet behaviors (Blackshaw and Blackshaw, 1994; Hrupka et al., 2000). Yet a definitive conclusion at this time cannot be established.

However, another possibility is that the short wooden fender allowed piglets to leave the farrowing hut and fender area at a younger age. Piglets on pasture may have engaged in more walking, playing, running, and rooting activities (Blackshaw et al., 1997; Cox and Cooper, 2001; Johnson et al., 2001) compared with piglets confined to the farrowing hut and fender area. Although increased activity may stimulate muscle accretion (Bekoff and Byers, 1998; Peterson et al., 1998; Gentry et al., 2002), if the piglets suckle infrequently yet are more active, they may utilize more energy, which could result in a lighter litter weight at weaning. We cannot say if this effect was caused by changes in sow or piglet (or both) behavioral patterns. These ideas would need to be evaluated in controlled studies to determine the factors that lead to a lighter litter at weaning. In addition, it would be helpful to record the day of lactation that fenders are removed from the farrowing hut using the criterion that half of the litter was no longer confined. If the lower wooden fender allowed litters out onto pasture days earlier than those litters born into a farrowing hut that had a tall metal fender attached, then this may help to explain some of the differences noted in performance.

Stillbirth rates between parity 1 and parity 2 sows were not different, but there was a fender \times insulation \times parity effect. The number of piglets recorded as stillborns was lower when parity 1 sows farrowed in insulated farrowing huts with short wooden fenders attached, compared with insulated farrowing huts with tall metal fenders. Numerous theories on the causes of stillbirth piglets have been cited, such as birth order and environmental stress during farrowing. Earlier born piglets are less likely to be stillborn and larger litter size increases the incidence of stillborn piglets (Glastonbury, 1976). However, litter size for parity 1 sows that farrowed in insulated farrowing huts with tall metal fenders attached was lower (10.5 ± 0.29 total piglets born/litter) than litters born into insulated farrowing huts with short wooden fenders (12.9 ± 0.28 total piglets born/litter). It is unclear why this result was obtained, and the difference in total piglets born may simply be a random effect. The litter size covariate made some accommodation for these differences so that a better estimate of treatment effects could be calculated.

In Exp. 2, no performance differences were found for fenders' front style (board or a roller). However, there may be some additional considerations. Firstly, one must consider the height of boards and rollers fixed onto the fender. Gilts may find the task of climbing over a fender partition set for the height of older parity sows more cumbersome. If she experiences problems climbing back over the partition, she may choose to return less frequently to her hut, which could have a detrimental effect on the litter performance (Bøe, 1994; Frampton et al., 2000; Marchant et al., 2000). Secondly, gilts and sows may show a preference for rollers compared to boards (Hemsworth and Cole-

Table 3. Least squares means and standard errors for main effects of fender front (board [MT-b] vs. roller [MT-r]) for the performance of sows and their litters from Exp. 2^a

| Measure | Fender fronts | | P-values |
|--|---------------|-------------|----------|
| | Board | Roller | |
| Number of sows and litters | 164 | 167 | |
| Piglets born, No./litter | 11.7 ± 0.34 | 11.4 ± 0.34 | 0.52 |
| Piglets born alive, No./litter | 10.9 ± 0.28 | 10.5 ± 0.29 | 0.36 |
| Stillbirths, No./litter | 0.8 ± 0.18 | 1.1 ± 0.14 | 0.19 |
| Litter birth weight, kg | 14.3 ± 0.55 | 14.9 ± 0.45 | 0.44 |
| Avg. piglet birth weight, kg | 1.5 ± 0.07 | 1.5 ± 0.06 | 0.95 |
| Piglet mortality, No. | 2.6 ± 0.21 | 2.4 ± 0.21 | 0.45 |
| Mortality, % | 23.7 ± 2.28 | 24.8 ± 2.34 | 0.74 |
| Days of lactation | 21.6 ± 0.84 | 22.5 ± 0.86 | 0.47 |
| Piglets weaned, No./litter | 7.9 ± 0.18 | 7.7 ± 0.18 | 0.50 |
| Litter wean weight, kg | 46.1 ± 1.40 | 46.7 ± 1.39 | 0.99 |
| Avg. piglet wean weight, kg | 5.9 ± 0.12 | 5.9 ± 0.12 | 0.21 |
| Number of missing piglets ^c | 0.4 ± 0.07 | 0.4 ± 0.07 | 0.66 |

^aBlock nested within fender × insulation was used as the error term.

^bP-value fender design by insulation status interactions were not significant ($P > 0.05$).

^cMissing piglets due to predation, piglet wandering off, and unknown causes.

man, 1998). From this study, we have speculated that the roller may be better for the sow because the plastic may be softer on her udder and the rolling action may help her over the partition. No studies have assessed the ease for the sow to climb over a fender partition that has either a board or roller front and a behavioral scoring system would be of interest to determine sow preference and to relate this to udder condition.

Management

The important role of the stockperson has often been ignored, yet stockperson skills play a pivotal role in the productivity of the unit (Friendship et al., 1986; Hemsworth and Coleman, 1998). Prior to piglets being born, the stockperson can provide a dry, clean and well-bedded farrowing hut. They can interact with the sows to gain their trust and be observant around parturition, noticing and treating farrowing problems (Dellmeier and Friend, 1991). Once the sow has farrowed, it becomes crucial to carry out routine tasks quietly and efficiently so as not to stress either the sow or her litter. In outdoor farrowing, routine tasks can become more complex with sows having the freedom to move and interact with the stockperson. Fender design may aid the stockperson in conducting their tasks, for example, at the time of processing. Our study demonstrated that when two people processed piglets, it required 44% more total stockperson hours to accomplish the task per litter, and tall metal fenders overall took longer than short wooden fenders. If one stockperson can process a litter, this will obviously be a more efficient use of labor. However, there are always occasions when a sow may become aggressive and two stockpersons might be preferred from an occupational safety perspective. The tall metal fender de-

sign confined the sows better, which resulted in improved stockperson safety.

Climate

The lower critical temperature for the individual neonatal piglet is approximately 34°C; however, the sow has an optimal air temperature range of 15 to 20°C (FASS, 1999). In comparison to other species, the newborn piglet is very poorly equipped to deal with the environment outside of the sow. They are fragile due to a lack of coat hair, a large surface area: body weight ratio, lack of suitable energy reserves, and poor body thermostability at birth (Bowman et al., 1996). The neonatal piglet, therefore, can rapidly become hypothermic in a cold environment. Chilling can result in reduced vigor, increased mortality, and decreased performance (Mount, 1963; Curtis, 1995). Indoor-intensive systems have solved many of these problems by providing climatic zone control through cool sprays for the sow and heat lamps or mats for the piglets (Heard et al., 1986; McGlone et al., 1988; Bull et al., 1997). In an outdoor situation, the temperature goals are less easy to achieve, but the provision of substrates to build a nest and to provide warmth are important considerations (Algers and Jensen, 1990; Curtis, 1995). Edwards et al. (1995) compared insulated and uninsulated farrowing huts in Scotland and reported that although temperature profiles from the two hut types indicated that insulation significantly reduced the diurnal air temperature at piglet level, no benefits with regard to piglet survival or growth rate were noted. In our climate, the insulation status of the farrowing hut independent from fender design did not provide any performance benefits for the sow and her litter.

Descriptive temperature profiles collected from insulated and uninsulated huts in this study indicated that outside temperatures overall were slightly lower compared to inside the farrowing huts but the effect was not significant.

Implications

The design of the farrowing hut is critical to maximize sow and litter performance when housed on pasture. Taller metal fenders may provide added stockperson safety at times of litter handling and management, but in this study, they did not save time when processing litters. Acceptable litter productivity was obtained with both the short wooden and taller metal fenders. However, it is not recommended to combine short wooden fenders and uninsulated farrowing huts because a lighter litter was weaned compared with other fender by insulation combinations, which would result in a cost disadvantage for the producer. Therefore, managers wishing to implement either a new fender design, a new fender front, or to insulate the farrowing hut, may base their decisions through personnel preference and/or longevity of the product, rather than on any potential performance benefits.

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