

Prewaning mortality in loose-housed lactating sows: Behavioral and performance differences between sows who crush or do not crush piglets

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Accepted 1 June 2006

Available online 14 August 2006

Abstract

The majority of piglet deaths occur within the first 72 h after parturition, with crushing by the sow as the most common cause of preweaning mortality. The aim of this study was to compare the behavior and performance of sows that killed piglets (CR) to those that did not (NC) inside a farrowing hut within the first 72 h after parturition. A total of 336 sows and their litters were used for comparisons. CR sows had more ($P < 0.01$) piglets born/litter and born alive/litter than NC sows. Mortality was higher ($P < 0.01$) for CR sows, with most piglet mortality in the first 72 h and there was a trend ($P = 0.06$) for CR sows to wean fewer piglets/litter than NC sows (7.8 ± 0.20 versus 8.4 ± 0.26), respectively. Behaviors were collected by time-lapse video on 20 sows, 10 from each group. Four sow postures: walking, standing, sitting and lying; four sow behaviors: pawing, rooting, nursing interval and nursing duration; and one sow location: out of hut were recorded. NC sows had a longer ($P = 0.03$) parturition compared to CR sows. Time (min) spent outside the farrowing hut did not differ between groups over the first 2 days, but on day 3 NC sows spent more ($P = 0.01$) time outside of the farrowing hut (20.2 ± 4.7) compared to CR sows (40.4 ± 4.8). NC sows spent more time pawing ($P < 0.01$) than CR sows (5.2 ± 0.41 min versus 1.7 ± 0.38 min) but no differences were found for all other behaviors ($P > 0.05$). There were no ($P > 0.05$) group differences for sow lying postures.

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✠ Dr. Julie Morrow died on January 5, 2003; however, she played a critical role in the completion of this work.

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One hour prior to piglet mortality 62.5% of CR sows moved from lying sternal to lying lateral, 25% moved from lying lateral to lying sternal and 12.5% of CR sows went from standing to lying lateral. In conclusion, CR sows spent more time inside the farrowing hut on day 3, spent more time lying on their sternum prior to crushing a piglet and the behavioral sequence associated with crushing piglets was a shift in lying postures rather than a transition from sitting or standing to lying.

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Keywords: Behavior; Farrowing house; Mortality; Outdoor; Sow

1. Introduction

In the UK, 25% of the total swine production is outdoors (Edwards et al., 1995), in the USA approximately 2% of the herd is housed outdoors (NAHMS, 2000). Allowing the gilt/sow increased mobility at the time of parturition may be detrimental for the well-being of her piglets, if, for example, the sow frequently alters her posture (Cronin and Cropley, 1991; Weary et al., 1996), if the sow is unresponsiveness to her piglets distress calls (Hutson et al., 1991; Hutson, 1993) or does not nurse frequently (Bryant et al., 1983; Jensen, 1988; Spinka et al., 1997). These factors could result in increased preweaning mortality and a lighter litter at weaning. Edwards et al. (1994) and Marchant et al. (2000) reported that during the first 72 h immediately following farrowing, 75% of all preweaning mortality can occur, yet the unrestricted and undisturbed post-farrowing behavior of the lactating sow inside a farrowing hut, has only received limited attention (Vieulle et al., 2003). The aim of this study was to compare the behavior and performance of loose-housed outdoor lactating sows that killed piglets within the first 72 h after parturition compared to those that did not kill piglets.

2. Animals, materials and methods

2.1. 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 hypopneumonia). Research was conducted from July to November 2000 at the Sustainable Pork FarmTM situated in an area with a dry steppe climate producing mild winter temperatures near Lubbock, TX, USA.

2.2. 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 weeks later using real time ultrasound. Pregnant sows were then moved into a gestation paddock. In the gestation radial sows were kept in 16, 0.4 acre paddocks which had 24 sows per 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, one paddock of gestation sows were transferred to the farrowing paddock. In farrowing, this larger gestation paddock was split into three smaller farrowing paddocks containing eight sows per farrowing paddock. Each farrowing paddock was 0.4 ha. Single stranded electrical wire (12 A) surrounded each farrowing paddock, which was at a height of 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 situated to the left side of the 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 (0.51 m × 1.19 m) over the open window. Closure rate was the same between all sows in and across pastures.

All farrowing huts had their hut opening and door orientated south. Short chopped wheat straw was used for bedding. Tall metal fenders (0.9 m height × 2.7 m width at the back of the hut and 0.7 m at the front × 1.60 m length) with a PVC roller (0.12 m × 0.12 m × 0.64 m). Fenders are partitions that are fixed onto the front of the farrowing which allows the sow-unrestricted access to the farrowing hut and paddock, but restricts young piglets to the farrowing hut and fender area (Johnson and McGlone, 2003). Fenders were attached after the sow had chosen her farrowing hut and prior to piglets being born. 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.

Sows were fed once daily at 0800 a completely balanced sorghum based diet (CP 16%; 1535 kcal 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 (2–9 kg/day; 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 days of age or less. For older litters, straw was added twice weekly or as required.

2.3. Climatic measurements

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 temperatures (°C), percentage relative humidity (RH, %), wind speed (km/h) and precipitation (cm). Measurements were recorded in 10-min intervals. Daily weather measurements were averaged to determine daily maximum and minimum values for each month of the study (Table 1).

2.4. Performance measurements

A total of 336 lactating sows (genetic line is a Camborough C-22, PIC) and their litters' records were used for performance comparisons. Two groups of sows were compared; sows that killed piglets (defined as CR [these sows were observed from the video tapes to kill one or more of their piglets in the first 72 h after parturition] compared to sows that were not observed to kill a pig or piglets in their litter over the first 72 h (NC) inside a farrowing hut.

Sows ranged over five parities: parity one ($n = 26$ CR and $n = 32$ NC), parity two ($n = 36$ CR and $n = 20$ NC), parity three ($n = 36$ CR and $n = 17$ NC), parity four ($n = 75$ CR and $n = 38$ NC) and parity five ($n = 35$ CR and $n = 21$ NC). For all litters, piglets were counted and weighed at birth and weaning. All piglets were processed at day 4 of age after filming so that the sow and piglet behaviors were not interrupted. Piglets were weaned once the average age/paddock was 22 days (22.01 ± 0.44 days for CR sows and 21.50 ± 0.57 days for NC sows), respectively. Sows were weighed on the day that she entered the farrowing paddock and on the day she returned to the breeding paddock.

2.5. Classification of piglet mortality

Total number of piglets per litter included piglets born alive, mummies and stillbirths. Stillborns (STIL) were recorded as any piglet found dead during or shortly after farrowing and that had not breathed. Prewaning piglet mortality was defined as any piglet that was born alive but died before weaning. Piglets

Table 1
Weather parameters for Sustainable Pork Farm™, Lubbock, TX, July–November 2000

Climatic parameter	Month				
	July	August	September	October	November
Air temperature, °C					
Minimum ^a	18.9	17	13.3	10.7	−0.01
Maximum ^b	37.1	38.1	34.7	23.9	13.3
Average	27.2	27.1	23.5	16.3	5.5
Relative humidity, %					
Minimum ^c	81.2	70.2	63.6	87.1	89.2
Maximum ^d	28.3	24.4	20.5	45.5	43.4
Average	53.9	44.3	39.2	68.2	68.7
Precipitation, cm	0.03	0.2	0.1	5.7	14.4
Wind velocity, km/h	27.7	23.5	28.9	33.8	30.1

^a Average minimum daily temperature (°C).

^b Average maximum daily temperature (°C).

^c Average minimum relative humidity (%).

^d Average maximum relative humidity (%).

killed within the first 72 h had their age, sex, weight and primary and secondary causes of preweaning mortality determined by the caretaker through internal and external necropsy of the heart, lungs, stomach and skin of the piglets on the day of death. Three categories classified preweaning mortality: starvation (STA) was defined if the stomach and intestines of the piglet contained no milk residues. Starvation and crushed/step on (NSCR) was classified if the piglet displayed one or more of the following: bruising to the body, excessive blood in the heart and lungs, protrusion of internal organs from the body cavity and no milk residues in the stomach or intestines. Suckled and crushed/step on (SUCR) was the same as previously described but milk residues were present in the piglets stomach and (or) intestines. After 72 h until weaning, piglets that died (located inside the farrowing hut, fender or farrowing pasture) were recorded but cause of death was not determined (reported as piglet mortality, no. per litter and mortality, %).

Piglets that could not be accounted for in either of these locations were classified as missing. Processed piglets that did not die before weaning but were not weaned were classified as missing.

2.6. Sow, posture, behavior and location measurements

Twenty lactating C-22 sows and their litters were used for behavioral comparisons for sows that killed piglets (CR; $n = 10$) or did not kill piglets (NC; $n = 10$) over the first 72 h after parturition. Sows ranged over four parities, parity two ($n = 2$ CR and $n = 2$ NC), parity three ($n = 3$ CR and $n = 1$ NC), parity four ($n = 3$ CR and $n = 5$ NC) and parity five ($n = 2$ CR and $n = 2$ NC). These 20 sows generated 1440 h of video for behavioral analyses.

A plastic shed inside the central hub area of the farrowing pasture housed four time-lapse video recorders (VCR; Model AG-6540, Panasonic Matsushita Co. Ltd., Japan), which were set to record in 24 h mode, 2.5 frames/s. Each VCR contained an RS-232C interface adaptor (AG-IA671; Panasonic Matsushita Co. Ltd.). VCRs were connected to a video switcher (VS-81V Model 625120, Kramer Electronics Ltd., Israel) and this was connected to one Panasonic black and white monitor so that camera angles and picture clarity could be checked daily. Four farrowing huts were positioned along the fence line at 45, 60, 75 and 90 m, respectively, from the central hub (as previously described by [Rachuonyo et al., 2002](#)). A 41 cm × 41 cm square was cut into the top center of each farrowing hut and a custom made protective 24 gauge galvanized steel camera hut ([Fig. 1](#)) was fixed onto the farrowing hut (Apex Sheet Metal, Lubbock, TX). The lid was hinged so that the camera could be easily adjusted from inside the camera hut unit.

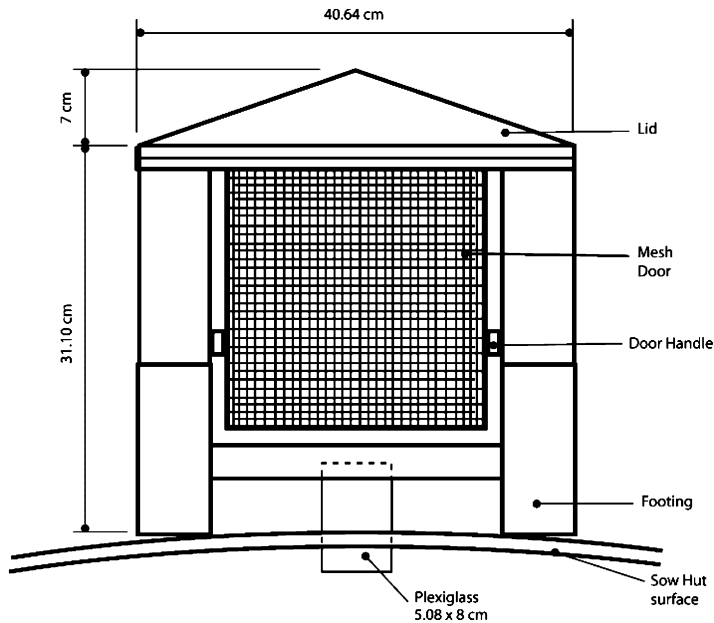


Fig. 1. Schematic drawing of the camera hut unit affixed onto the farrowing hut to continually record sow behaviors. Diagram not to scale.

The camera hut unit (38.10 cm × 40.64 cm) contained filters on each side to allow air to circulate around the camera while preventing dust particles entering. A clear plexi glass tube (5.08 cm × 8 cm) was inserted into a predrilled hole at the base of the camera hut unit to protect the lens of the camera. This tube protruded into the farrowing hut and on either side of the camera one 12 V mini bayonet bulb was suspended from the floor of the hut unit. This light source provided ample light for the camera to work at night but was minimal so that it did not interfere with the behavior of the sow and her litter (Leon, 1985). One black and white (Model WV-BP 332, Panasonic Matsushita Co. Ltd.) 12 V camera was positioned inside the camera hut unit with the lens directed into the farrowing hut. Each camera had a 1.8–3.6 mm variable focal lens (Computar Japan). Cameras were held in position by four steel rods welded inside the camera hut unit. Each hut had one Astron Model RS-4A (Astron Coop., Irvine, CA), 13.8 V transformer to provide power for the camera and light.

Every week four cameras were set up onto four farrowing huts. The sows were allowed to choose their huts and farrow just as would happen in the production world. After the sows had farrowed and lactated for 72 h these tapes were removed and looked at. If we had two sows that had crushed piglets and two that had not we considered this to be a complete balanced group of sows (two CR and two NC). If in the farrowing group we had, for example, three CR and one NC we discarded these tapes, moved the cameras around to the next farrowing group and started again. From the sows behavior and performance five groups met the criterion, one group from each of the following months were included in this study: July, August, September, October and November, respectively.

The acquisition of all the behavioral measures were conducted by one trained observer who viewed the tapes using continuous observation (6.25 frames/s) and entered data from the videotapes into the computer using the Observer software (The Observer, Ver. 5, Noldus Information Technology, Wageningen, The Netherlands).

2.6.1. Length of parturition

Behavioral measures were obtained from video records. The length of parturition (min) was determined by: birth of the last piglet born – birth of the first piglet born = parturition length (min).

Table 2

Description of the sow posture, behavior and location measurements (min) for PIC sows that either killed piglets (CR; $n = 10$) or did not kill piglets (NC; $n = 10$) inside the farrowing hut from July to November 2000

	Definition
Posture	
Walking	Any action while the sow was upright and moving
Standing	Assuming or maintaining an upright position on extended legs but remaining stationary
Sitting	Most of the sow's body weight and the posterior of her body trunk were in contact and supported by the ground
Lying (lateral and sternum)	Side contacting the ground or underside contacting the ground
Sow lying position	
Vertical	Snout of sow facing toward the front or back wall of the farrowing hut
Horizontal	Snout of sow facing the one of the side walls of the farrowing hut
Diagonal	Snout of sow facing one of the four corners of the farrowing hut
Behavior	
Pawing	Front leg making a scooping motion, generally directed toward the ground
Rooting	Thrusting snout into the straw and moving the straw around
Nursing interval	Period of time when the sow exposed her teat line and 80% of the piglets responded by massaging the teat area until the next nursing cycle began
Nursing duration	Nursing duration was a collection of four phases, including an initial massage phase, a phase when the piglets stopped massaging, true suckling (which lasts for about 14 s while milk is ejected), and a final massage phase, which is variable in length began when 80% of the piglets engaged in initial massage and ended when less than 80% of the litter was attached to the teats
Location	
Time spent out of hut	Hind legs were over the door step into the fender area and ended when the sow crossed over the step with both hind legs back into the farrowing hut

Behaviors adapted from Hurnik et al. (1995).

2.6.2. Continuous sow behavior

Four sow postures: walking, standing, sitting and lying (lateral and sternum); four sow behaviors: pawing, rooting, nursing interval and nursing duration; and one sow location: out of hut (min) were recorded (Table 2).

2.6.3. Sow lying position

Twelve sow lying positions were recorded while sows were inside their farrowing huts. Four positions were classed as vertical, four positions horizontal and four positions diagonal (Fig. 2). These 12 lying positions were then collapsed into 3 lying categories: vertical (Position1), horizontal (position 2) and diagonal (position 3) for final analysis as there were no differences between the four vertical positions the four horizontal positions or the four diagonal positions. Recording of the sows' lying position began from the birth of the first piglet and each time she made a lying positional change it was recorded continually for the first 72 h of parturition.

2.6.4. Time required from reentering the farrowing hut to lying down

Time required (min) by each sow to reenter the farrowing hut and assume a lying position was calculated. Reentry was defined as the precise point when the back legs of the sow crossed over the farrowing hut step into the farrowing hut. Timing began from this point of entry and lasted until the sow assumed either a lateral or sternal lying position.

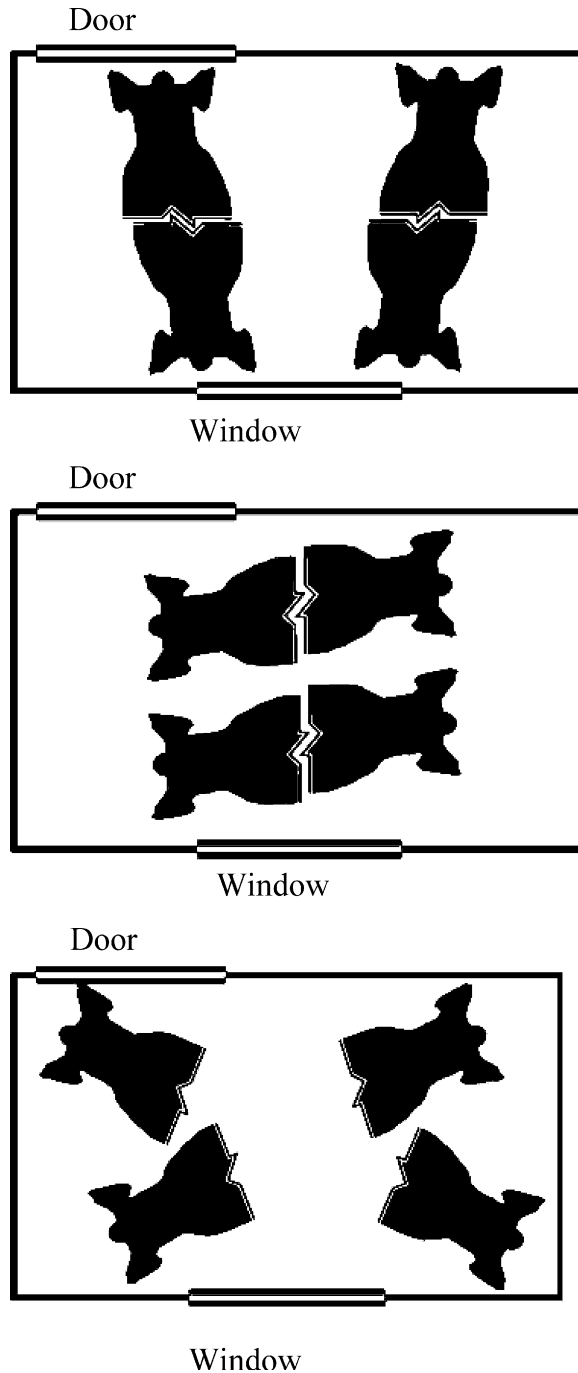


Fig. 2. Lying positions for PIC USA sows ($n = 20$) inside an English style-farrowing hut over the first 72 h after parturition from July to November 2000. Position 1: vertical lying positions for the lactating sow inside an English style-farrowing hut. Position 2: horizontal lying positions for the lactating sow inside an English style-farrowing hut. Position 3: diagonal lying positions for the lactating sow inside an English style-farrowing hut.

2.6.5. Sow behavior 1 h prior to piglet mortality

Continuous sow behavioral sequences 1 h prior to piglet mortality were collected to help identify if one behavioral pattern made by the sow resulted in piglet deaths. Two sows killed piglets in blocks 1–5.

Ten sows that killed a piglet(s) (labeled as CR) over the first 72 h were identified from the video tapes. For the 10 CR sows, the precise times that the piglets died were determined. The point of piglet death became the end point and from here the observer worked backwards to determine the last four behaviors sequentially performed by CR and NC sows immediately before piglet mortality were collected and descriptively reported.

3. 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 (containing one sow with her litter) within each block (defined below) with two groups: sows that either killed piglets within the first 72 h (CR) versus sows that did not kill piglets within the first 72 h (NC) of parturition.

Performance data, length of parturition (min) and sow behaviors 1 h prior to piglet mortality were analyzed as a randomized block design with date sows entered farrowing as the block ($n = 5$). A block was a set of sows of the same parity that farrowed at the same time. Each block for sow parturition and sow behavior consisted of two NC sows and two CR sows.

The model-included treatment group, block nested within group (CR versus NC) (error a), and time (min) and treatment group by time. Number of piglets born per litter and sow parity were included in the model as a covariate for parturition duration in min was transformed to achieve a normalized distribution for behaviors 1 h prior to piglet mortality.

Time spent outside of the farrowing hut, continuous sow behavior over the first 72 h, time required for the sow to enter the farrowing hut and to assume a lying position and sow lying position were analyzed as a randomized block design split plot k ($n = 5$). The statistical model main plot included treatment group, block nested within group (CR versus NC) (error term a) and time and treatment group by time. The sub-plot included day, day by group interaction and residual error for the sub-plot.

4. Results

4.1. Performance measurements

A greater number ($P = 0.002$) of piglets died in the first 72 h in CR sows compared to the NC sows that were filmed. However, NC sows killed more piglets (2.3 ± 0.52 per litter) from day 4 until weaning, which resulted in a similar number of piglets weaned per group compared to CR sows. All other performance parameters were not ($P > 0.05$) different between groups (Table 3).

When all sows that farrowed between July and November 2000 were compared, CR sows had more ($P = 0.01$) piglets born/litter (12.5 versus 10.4) and more piglets born alive/litter (11.5 versus 9.7). Percent mortality was higher ($P < 0.01$) for CR sows during the first 72 h after parturition and was similar ($P = 0.65$) from day 4 until weaning compared to the NC sows. This resulted in CR sows having a higher (34.6%; $P < 0.001$) overall preweaning mortality compared to NC sows (11.3%). There were no ($P > 0.05$) differences in stillborns, the number of piglets weaned or missing piglets between the groups. For litter birth and weaning weights and sow starting, ending and weight differences there were no ($P > 0.05$) differences between (Table 4). Using total number of piglets born/litter to predict overall piglet mortality had a low R^2 for both CR ($R^2 = 18.4\%$) and NC sows ($R^2 = 18.5\%$), respectively.

Table 3

Least squares means and standard errors for (a) number of piglets born, born alive/litter, number of piglets dead/litter, preweaning mortality, stillbirths and missing piglets for PIC sows that either killed piglets (CR) or did not kill piglets (NC) (b) performance of PIC sows and their litters for those that either killed piglets (CR; $n = 10$) or did not kill piglets (NC; $n = 10$) over the first 72 h after parturition from July to November 2000

Performance measure	Groups		P-values
	CR	NC	
Number of sows and litters	10	10	
Piglets born, no./litter	13.0 ± 1.31	13.3 ± 1.39	0.86
Piglets born alive, no./litter	11.1 ± 1.09	12.4 ± 1.16	0.38
Stillbirths	1.9 ± 0.52	0.9 ± 0.56	0.18
No. piglets alive/litter, days 0–3	8.8 ± 1.01	12.4 ± 1.07	0.02
No. piglets alive/litter, day 4 to wean	8.2 ± 0.96	10.1 ± 1.02	0.17
No. piglets alive/litter, total ^a	7.5 ± 0.84	9.6 ± 0.89	0.12
Piglet mortality, no./litter, days 0–3	2.3 ± 0.40	0 ± 0	0.002
Piglet mortality, no./litter, day 4 to wean	0.6 ± 0.49	2.3 ± 0.52	0.08
Piglet mortality, no./litter, total	2.9 ± 0.58	2.3 ± 0.61	0.50
Mortality, %, days 0–3	20.7 ± 2.92	0 ± 0	0.001
Mortality, %, day 4 to wean	6.8 ± 4.38	20.7 ± 4.67	0.12
Mortality, %, total	27.5 ± 4.14	20.7 ± 4.42	0.45
Number of missing piglets	0.7 ± 0.34	0.5 ± 0.36	0.95
Litter birth weight, kg/litter ^b	13.3 ± 3.02	12.8 ± 3.60	0.92
Average litter birth weight, kg/litter ^c	1.1 ± 0.20	1.4 ± 0.24	0.53
Days of lactation	21.5 ± 1.31	21.0 ± 1.40	0.81
Litter wean weight, kg/litter	48.2 ± 6.45	50.8 ± 6.85	0.79
Average litter wean weight, kg/litter	5.8 ± 0.60	5.6 ± 0.64	0.85
Sow start weight, kg ^d	265.9 ± 13.93	250.4 ± 14.50	0.47
Sow end weight, kg ^d	241.0 ± 11.62	237.6 ± 15.89	0.88
Sow weight difference, kg ^d	−27.8 ± 4.08	−16.6 ± 5.58	0.20

Two time periods, 0–3 and 4–22 days and overall totals from July to November 2000.

Block nested within group was the error term parity was used as a covariate.

^a No. piglets alive/litter total also defined as the total number of piglets weaned/litter.

^b Litter birth weight is the total weight of all piglets in the litter summed together.

^c Average litter birth weight is the total litter birth weight/the number of piglets within that litter.

^d Weight of sow on the day she entered the farrowing paddock and on the day she returned to breeding after piglets were weaned.

A total of 19 piglet deaths (11 males and 8 females) for the 20 sows filmed within the first 72 h were recorded. A total of three piglets were stillborn (two from CR sows and one from NC). Of the remaining 16 piglets that died within 72 h after parturition from the CR sows, 11 were SUCR, 4 were NSCR and 1 was classified as STA. When mortality was broken down over the first 3 days, a total 12 piglets were either stillborn or died on day 1, with 5 piglets dying on day 2 and 2 piglets on day 3. The average weight for stillborn piglets was 1.2 ± 0.21 kg and for the 16 piglets from the 10 CR sows that were killed over the first 72 h their weight was 1.4 ± 0.09 kg.

4.2. Sow behavior, posture and location measurements

4.2.1. Length of parturition

NC sows had a longer ($P = 0.03$) duration of parturition compared to CR (217 ± 24.5 min versus 134 ± 22.6 min).

Table 4

Least squares means and standard errors for (a) number of piglets born, born alive/litter, number of piglets dead/litter, preweaning mortality, stillbirths and missing piglets for PIC sows that either killed piglets (CR) or did not kill piglets (NC) (b) performance of PIC sows and their litters that either killed piglets (CR) or did not kill piglets (NC) over the first 72 h after parturition from July to November 2000

Performance measure	Groups		P-values
	CR	NC	
Number of sows and litters	208	128	
Piglets born, no./litter	12.5 ± 0.21	10.4 ± 0.28	0.001
Piglets born alive, no./litter	11.5 ± 0.21	9.7 ± 0.27	0.001
Stillbirths	1.0 ± 0.10	0.7 ± 0.13	0.07
No. piglets alive/litter, days 0–3	9.2 ± 0.20	9.7 ± 0.26	0.15
No. piglets alive/litter, days 4–22	8.1 ± 0.21	8.6 ± 0.27	0.15
No. piglets alive/litter, total	7.8 ± 0.20	8.4 ± 0.26	0.12
Piglet mortality, no./litter, days 0–3	2.3 ± 0.07	0.0 ± 0.00	0.001
Piglet mortality, no./litter, days 4–22	1.1 ± 0.12	1.1 ± 0.16	0.94
Piglet mortality, no./litter, total	3.4 ± 0.14	1.1 ± 0.18	0.001
Mortality, %, days 0–3	20 ± 0.57	0.0 ± 0.00	0.001
Mortality, %, days 4–22	13.6 ± 1.00	11.3 ± 1.53	0.65
Mortality, %, total	34.6 ± 1.18	11.3 ± 1.53	0.001
Number of missing piglets	0.3 ± 0.06	0.2 ± 0.08	0.37
Litter birth weight, kg/litter ^a	14.6 ± 0.44	14.3 ± 0.54	0.70
Average litter birth weight, kg/litter ^b	1.5 ± 0.03	1.6 ± 0.04	0.37
Days of lactation	22.0 ± 0.44	21.5 ± 0.57	0.49
Litter wean weight, kg/litter	45.0 ± 1.19	48.6 ± 1.55	0.08
Average litter wean weight, kg/litter	5.89 ± 0.11	6.0 ± 0.14	0.53
Sow start weight, kg ^c	260.8 ± 2.51	258.4 ± 3.24	0.55
Sow end weight, kg ^c	239 ± 2.80	238.4 ± 3.49	0.36
Sow weight difference, kg ^c	-20.1 ± 1.96	-20.9 ± 2.47	0.65

Two time periods, 0–3 and 4–22 days and overall totals from July to November 2000.

Block nested within group was the error term and sow parity was used as a covariate.

^a Litter birth weight is the total weight of all piglets in the litter summed together.

^b Average litter birth weight is the total litter birth weight/the number of piglets within that litter.

^c Weight of sow on the day she entered the farrowing paddock and on the day she returned to breeding after piglets were weaned.

4.2.2. Continuous sow behavior

For continuous sow behavior over the first 72 h after parturition, NC sows spent more time pawing ($P = 0.01$) than CR sows. All other behaviors were not different ($P > 0.05$) between groups nor were the group by day interactions significant (Table 5). There were no differences in the nursing interval ($P > 0.05$) between groups (40 ± 1.95 min versus 40 ± 2.1 min) and there was no ($P > 0.05$) group by day interactions.

A trend was found ($P = 0.06$) for the day effect for interval between nursing bouts – the interval increased as the litter became older (36 ± 2.4 , 42 ± 2.4 and 42 ± 2.4 min, respectively, for days 1, 2 and 3). The time required for piglets to nurse the sow was not different ($P > 0.05$) between groups nor was the group by day interaction significant. There was a difference ($P < 0.01$) over day in the duration of nursing behavior (Fig. 3); nursing duration was longer on day 1 than on day 2 or 3.

Time spent outside of the farrowing huts did not differ ($P = 0.26$) between groups over days 1–2 (8 ± 3 , 22 ± 3.19 and 30 ± 3.3 min). However, Time spent outside the farrowing hut did

Table 5

Least squares means and standard errors averaged over 24 h for behaviors performed by PIC sows that either killed piglets (CR; $n = 10$) or did not kill piglets (NC; $n = 10$) inside the farrowing hut from July to November 2000

Behavioral measure (min)	Groups		<i>P</i> -value
	CR	NC	
Number of sows	10	10	
Walking	2.4 ± 0.57	2.5 ± 0.62	0.87
Standing	7.9 ± 2.81	6.2 ± 3.03	0.68
Sitting	3.1 ± 2.20	6.5 ± 2.37	0.32
Lying lateral	570.4 ± 105.88	646.8 ± 114.21	0.64
Lying sternum	159.5 ± 47.18	164.8 ± 50.89	0.94
Pawing ^a	1.7 ± 0.38	5.2 ± 0.41	0.001
Rooting ^b	21.1 ± 6.66	36.2 ± 7.18	0.17
Nursing	295.3 ± 43.28	356.1 ± 46.69	0.37

Block nested within group was the error term used to test group effects.

^a Pawing behavior was defined as the front leg making a scooping motion, generally directed toward the ground.

^b Rooting behavior was defined as the sow thrusting her snout into the straw and moving the straw around. Pawing and rooting may be positive maternal behaviors to move sleeping piglets out of the sow's path before she assumes a lying position back inside the farrowing nest. A default behavior was recorded if the video was unclear to record a behavioral class. For groups there was no difference ($P = 0.26$) in unclear behaviors from the video recording with CR sows at 360.4 ± 145.5 min and NC sows at 192.8 ± 156.9 min.

differ between groups on day 3. NC sows spent more ($P = 0.01$) outside of the farrowing hut (20 ± 4.7 min) compared to CR sows (40 ± 4.8 min; Fig. 4).

4.2.3. Sow lying positions

There were no differences in lying positions when inside the huts for both groups ($P > 0.05$) position 1 (263 ± 68.6 min versus 158 ± 73.9 min), position 2 (698 ± 75.9 min versus 763 ± 81.9 min) and position 3 (301 ± 79.52 min versus 331 ± 85.8 min) for CR and NC sows, respectively. The day by group interaction was not significant ($P > 0.05$). Day influenced sow lying position inside the huts. Sows spent less time ($P = 0.04$) lying in position 2 and more time in position 3 by day 3 ($P < 0.01$; Fig. 5).

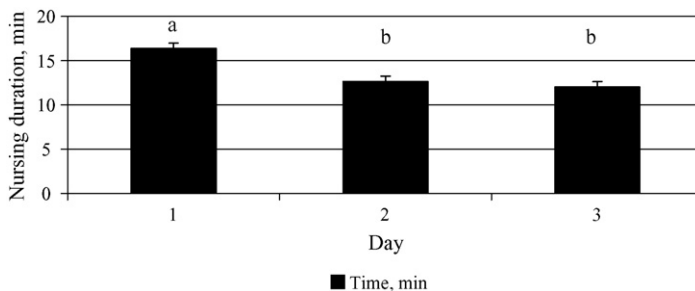


Fig. 3. Nursing duration (min) for PIC sows that either killed piglets (CR) or did not kill piglets (NC) over the first 72 h after parturition from July to November 2000. Least squares means and standard errors differ (a and b) (day, $P < 0.01$; $n = 20$). Residual error was the error term.

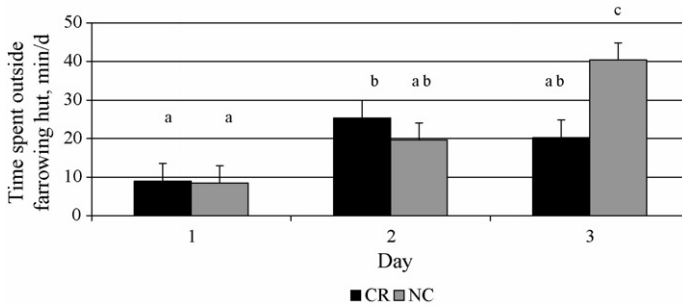


Fig. 4. Time spent outside of the farrowing hut (min) for PIC sows that either killed piglets (CR) or did not kill piglets (NC) over the first 72 h after parturition from July to November 2000. Least squares means and standard errors with a different letter (a–c) differ (group by day, $P = 0.01$; $n = 20$ litters).

4.2.4. Time required from reentering the farrowing hut to lying down

There were no ($P > 0.05$) differences between groups for day 1 (5 ± 0.6 min versus 5 ± 0.7 min), day 2 (5 ± 0.7 min day 1, 5 ± 0.7 min) or day 3 (5 ± 0.7 min day 3) or day by group interaction for CR and NC sows to enter and resume a lying position inside the farrowing huts.

4.2.5. Sow behavior 1 h prior to piglet mortality

Descriptive behaviors for the final four sow behaviors prior to piglet death resulted in, 62.5% of CR sows moving from lying sternal to lying lateral, 25% of the sows moved from lying lateral to lying sternal and 12.5% of CR sows transitioned from standing to lying lateral.

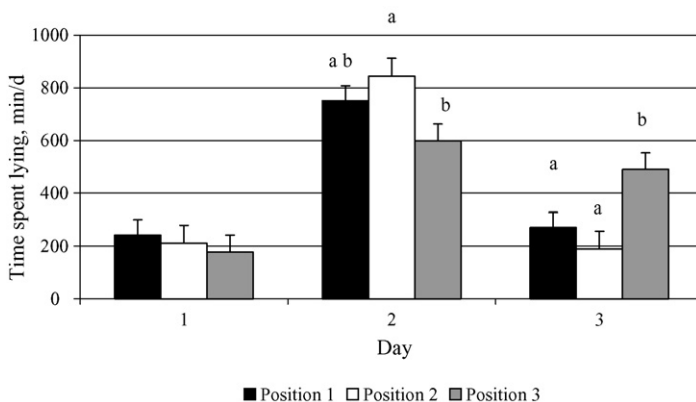


Fig. 5. Lying positions (min) for PIC sows that either killed piglets (CR) or did not kill piglets (NC) over the first 72 h after parturition from July to November 2000. Least squares means and standard errors with a different letter (a and b) differ (Day $P = 0.04$; $n = 20$ litters). The three sow lying positions were vertical (snout of sow facing toward the front or back wall of the farrowing hut), horizontal (snout of sow facing the one of the side walls of the farrowing hut) and diagonal (snout of sow facing one of the four corners of the farrowing hut).

5. Discussion

5.1. Performance measurements

Prewaning mortality is a concern for the USA swine industry, not only because it limits sow productivity and costs the swine industry US\$ 408 million annually (NAHMS, 2000) but it presents an obstacle in any attempt to improve piglet well-being. The complex phenomenon of piglet mortality has been well researched, with 30% of piglet losses attributable to a single factor and 70% attributed to multiple factors (Le Dividich et al., 1996). The mostly cited reason pertaining to piglet mortality is crushing by the sow (Marchant et al., 2000; NAHMS, 2000). In an outdoor pasture system with increased sow mobility, piglets may be exposed to an increased risk of being crushed or stepped on.

In our study, the piglets that died from the 10 CR sows within the first 72 h were removed from the hut, weighed, sexed and the cause of death was determined. This resulted in a very small sample size of 19, but the causes of mortality still reflected what other larger studies have reported (English and Morrison, 1984; Randall, 1972). For example, 7% of piglets were born dead and of the remaining piglets that died before weaning, 64% of the piglets were classified as suckled and crushed (SUCR), with 28% classified as not suckled and crushed (NSCR). In addition 63% of the piglets died on day 1, with this decreasing to 26 and 11% on days 2 and 3, respectively. This is in agreement with a study by Vieuille et al. (2003) reported that 63.6% of piglets were crushed in the first 12 h after birth.

When only referring to the 20 sow data set for other performance measures (sow and piglet weights, stillbirths and number of piglets born), there were no performance differences other than increased piglet mortality during the 0–3 days period among CR versus NC sows. However, the larger performance data set (Table 4) CR sows had more total number of piglets born per litter and piglets born alive per litter compared to NC sows. The difference between the smaller data set of 20 sows versus the larger performance data set of 336 sows could probably be attributed to the smaller sample size for the performance data set.

Interestingly, for the 20 sows that were filmed, CR sows killed 75.7% of all piglets in the first 72 h while NC sows killed the same amount between day 4 and weaning, which resulted in similar numbers of piglets weaned between the groups. However, when the larger group was compared, the CR sows had an unacceptable mortality rate at 34.6%, while NC sows were lower at 11% mortality. Although it is possible for the domestic sow of this genotype to carry a large litter the question of whether all sows in this type of system can successfully raise 10–12 piglets per litter to weaning is another consideration.

Producers would be encouraged to closely watch sows that wean large litters and recycle them back through the breeding herd, perhaps selecting out other sows who display a high preweaning mortality rate. In addition producers may wish to implement a better cross-fostering regime, which will address problems of large litter size allowing numbers to be evened out and piglets of similar size to be grouped together. However in an outdoor farrowing unit, where sows are rarely given oxytocin so that they farrow within a tight schedule, cross-fostering is not always that easy to achieve. The timing to foster piglets is critical and producers are encouraged to carry this out within 24 h of the sow farrowing (Fraser, 1979; Horrell and Bennett, 1981; Horrell, 1982). Repeated cross-fostering is not advised (Robert and Martineau, 2001) and recently the overall importance of cross-fostering was questioned by Young (2001) who demonstrated that by evening out litter sizes, smaller piglets gained less weight than piglets left in litters of mixed size.

5.2. Sow behavior, posture and location measurements

Understanding behavior before, during and after farrowing for sows housed outdoors is crucial when addressing the question of preweaning mortality (Stolba and Wood-Gush, 1989). Farrowing managers that have lactating sows housed in a pasture system face increased challenges. They may have reduced control over the timing of parturition and then may only be able to provide limited assistance if complications arise. Jensen (1986) conducted a detailed study on free ranging sow behavior and reported that parturition ranged from 85 to 180 min producing an average litter size of 10.6 piglets per litter. In our study, CR sows' parturition took an average of 134 min and they delivered 13 total piglets per litter. NC sows took longer (217 min) to farrow and had slightly larger litter sizes (13.3 piglets per litter) than CR sows. Interestingly, even though the caretaker was not always present at the time of parturition and NC sows had longer farrowing durations, stillbirth rates were within normal ranges (NAHMS, 2000) and farrowing complications were virtually non-existent.

One behavior of particular interest from this study was that NC sows invested more time in pawing (5.2 min versus 1.7 min) behavior compared to their CR counterparts. Pawing behavior seemed to be important because as the sow enters the farrowing hut and invests time into scooping/pawing the straw, it was noted that piglets who are resting and covered are disturbed, which encourages piglets to become active. Active piglets can in turn provide the sow with a visual cue of their presence and location in the hut.

Jensen (1988) and Csermely (1994) reported that free-ranging sows spent 76% of their total time budget lying in their nest, followed by nursing (16%). However, as litters get older, sows increasingly terminate nursing by shifting their posture to "hide" their teat line (Gotz, 1991; Puppe and Tuchscherer, 2000). Nursing patterns in the sow are usually stable 10 h after farrowing (Lewis and Hurnik, 1986). In this study no differences for either nursing duration or interval between the groups were observed. However, nursing duration decreased from days 1 to 2 (16–12 min) and nursing interval increased from days 1 to 2 (36–43 min). CR sows nursed for 37% and NC sows nursed 29% of their total time inside the farrowing hut which is slightly higher than that reported by Jensen (1988) and Csermely (1994). Interestingly, piglets in our study that were particularly small and had difficulty in attaching to a teat occasionally used alternative nursing strategies. For example, it was observed that these piglets would climb up onto the flank of the sow and nurse from the flank downwards instead of resuming the normal position of lying on the straw and attaching onto the teat. Additional piglet-intensive experiments need to be conducted to validate these observations further.

In our study, CR and NC sows spent 98% of their total time inside the farrowing hut over the first 72 h. Of this time budget, a large percentage of sow time was spent in a lying position (68% for CR sows and 65% for NC sows). For both groups, sows laid in a horizontal plane on day 2 and a diagonal plane by day 3. Few studies have reported lying postures through lactation, but general observations indicate sows increased their time facing the farrowing hut door when the caretaker or another sow approached her hut. It was likely that thermal fluctuations influenced lying patterns within the range observed in this study.

By day 3, NC sows spent increasing time away from their litter compared to CR sows. This may be advantageous, as sows that spend increased time away from their litter had a reduced risk of crushing piglets. This increased time away did not adversely affect weaning weight, indicating that sows frequently returned to nurse their piglets. Upon reentry into the farrowing hut, sows from both groups spent 5 min investigating the straw before lying. During this period, NC sows invested more time pawing the straw and piglets were often disturbed from sleeping and became active, running around the sows feet and head. This finding agrees with observations made by

Marchant et al. (2001) who highlighted the importance of increased piglet-directed behavior in reducing the number of dangerous lying events.

Descriptive behaviors for the final four sow behaviors prior to piglet death resulted in, 62.5% of CR sows moving from lying sternal to lying lateral, 25% of the sows moved from lying lateral to lying sternal and 12.5% of CR sows transitioned from standing to lying lateral. If this rolling occurred at the same time that nursing was initiated, the sow may have been unable to distinguish a piglet's distress call from piglets that were active at the teats. A piglet caught under its mother during nursing (several minutes) would have little chance of survival. Postural shift in lying behavior that may result in catching piglets under her flank or shoulder, has been reported elsewhere for sows in alternative indoor farrowing systems. Several workers studied the effects of sow rolling (lateral to sternum lying) on piglet mortality but their results varied widely. Olsson and Svendsen (1989) reported 7%, Marchant et al. (2001) recorded this at 25% and Weary et al. (1996) reported this at 75% of the total piglet deaths occurring for sows that rolled from lateral to sternal lying position. These disparities may occur due to different thermal environments affecting the amount of time piglets spend in proximity to the sow and (or) the different sow genotypes between the three studies. Sow genotypes may result in different body conformations, movements and behaviors and the sow may have different abilities in controlling her body movements (McGlone et al., 1998). However, it should be noted in this study that only 20 sows were studied. This is a relatively small sample size and therefore if there were other behavioral differences between CR and NC groups the smaller sample size may not be able to detect subtle statistical differences.

6. Conclusions

NC sows displayed more pawing behaviors and increased their time away from their litter compared to CR sows during the first 72 h after birth. Work to identify genes that have high heritability or environments that cause to positive maternal behaviors and to implement these genes into a breeding program may be advantageous for the future swine industry if producers wish to house their sows in alternative systems that allow increased sow mobility. This study provides behavioral targets that could be used in genetic or environmental approaches to reduce preweaning mortality of sows in loose housing systems.

Acknowledgements

This work was supported by USDA-Fund for Rural America, USDA-ARS, Consolidated Nutrition and Texas Tech Animal Science Research Funds. The authors thank J. Smith and A. Lewis for animal care and technical assistance.

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