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Resting Behavior of Piglets in Farrowing Crates Equipped with Heat Mats

Abstract
In-barn tests were conducted to study the resting behavior of piglets on heat mats in swine farrowing crates. An environmentally controlled farrowing room was set at 21.C (70.F) to simulate winter conditions in farrowing barns. Two enlarged crates [1.94 . 2.13 m (6.4 . 7 ft)] were used in the tests and each crate had a 0.6- . 1.2-m (2- . 4-ft) electrically heated mat. Mat surface temperatures of 33.C (91.F) and 35.C (95.F) were tested. Resting patterns of piglets on heat mats were recorded on videotapes using a time-lapse VCR and were subsequently analyzed. Heat mats provided a comfortable thermal environment to piglets as a low degree of huddling (10%) was observed. A difference of 2.C (3.6.F) in mat temperature (33.C vs. 35.C) caused no differences in the resting behavior or growth of the piglets. Piglets spent more time nursing than resting on heat mats during the first 24 h after birth. Heat mat usage by piglets was high (>50%) from day 2 to 5 and it started to decrease thereafter, a result of less need for heat as piglets grow. The area occupied by piglets on the mat averaged 0.044 m2/pig (0.47 ft2/pig) and 0.074 m2/pig (0.80 ft2/pig) for 1- and 14-day old piglets, respectively. The dynamic heat mat use behavior of the piglets indicated that a mat size of 0.37 m2 (4 ft2), as typically used in current commercial production facilities, could accommodate most of the space needs of a litter of 12 piglets; but larger mats (e.g., 0.56 m2 or 6 ft2) would be advisable to ensure the well-being of piglets under unfavorable (cool or drafty) environmental conditions when the mat needs to accommodate the entire litter simultaneously.

Keywords
Swine farrowing, Piglets, Localized heating, Heat mats, Resting behavior

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Q. Zhang, H. Xin

ABSTRACT. *In-barn tests were conducted to study the resting behavior of piglets on heat mats in swine farrowing crates. An environmentally controlled farrowing room was set at 21 ℃ (70 ℉) to simulate winter conditions in farrowing barns. Two enlarged crates [1.94 × 2.13 m (6.4 × 7 ft)] were used in the tests and each crate had a 0.6- × 1.2-m (2- × 4-ft) electrically heated mat. Mat surface temperatures of 33 ℃ (91 ℉) and 35 ℃ (95 ℉) were tested. Resting patterns of piglets on heat mats were recorded on videotapes using a time-lapse VCR and were subsequently analyzed. Heat mats provided a comfortable thermal environment to piglets as a low degree of huddling (10%) was observed. A difference of 2 ℃ (3.6 ℉) in mat temperature (33 ℃ vs. 35 ℃) caused no differences in the resting behavior or growth of the piglets. Piglets spent more time nursing than resting on heat mats during the first 24 h after birth. Heat mat usage by piglets was high (>50%) from day 2 to 5 and it started to decrease thereafter, a result of less need for heat as piglets grow. The area occupied by piglets on the mat averaged 0.044 m^2/pig (0.47 ft^2/pig) and 0.074 m^2/pig (0.80 ft^2/pig) for 1- and 14-day old piglets, respectively. The dynamic heat mat use behavior of the piglets indicated that a mat size of 0.37 m^2 (4 ft^2), as typically used in current commercial production facilities, could accommodate most of the space needs of a litter of 12 piglets; but larger mats (e.g., 0.56 m^2 or 6 ft^2) would be advisable to ensure the well-being of piglets under unfavorable (cool or drafty) environmental conditions when the mat needs to accommodate the entire litter simultaneously.*

Keywords. *Swine farrowing, Piglets, Localized heating, Heat mats, Resting behavior.*

Heat mats are gaining acceptance in North America for providing localized heating in swine farrowing facilities. Compared to traditionally used heat lamps, heat mats can provide a better microenvironment to piglets because of a large, uniformly heated surface. Zhang and Xin (2001) compared temperature distributions between 120-W electrical heat mats and 175-W heat lamps. They reported that the mat surface temperature remained almost constant across the mat, whereas the surface temperature on the floor mat under the 175-W heat lamp varied from a small high temperature zone of 49°C (120°F) to ambient temperature of 21°C (70°F). The non-uniform heating under the heat lamp caused large differences in the surface temperature of piglets among the litter, with the highest of 39.5°C (103.1°F) directly under the lamp and the lowest of 33.4°C (92.1°F) (Zhang and Xin, 2001). de Baey-Ernsten et al. (1995) reported that surface (floor) heating provided more uniform temperature in the pig rest area than overhead (radiant) heating. A uniform floor heating system resulted in less crowding and greater weight gain than did radiant heating systems.

Mat heating relies on conductive heat transfer from the heat mat to the piglets lying on the mat. Therefore, the mat surface temperature affects the resting behavior of piglets on heat mats. Little information is available in the literature on the resting behavior of pigs on heated surfaces. The objective of this study was to determine the duration/frequency of newborn piglets resting on heat mats at two different surface temperatures, as well as the mat size requirement based on resting behavior of piglets on the heat mat.

MATERIALS AND METHODS

The experiment was conducted in an environmentally controlled farrowing room. Fresh air was heated or cooled before entering the room and distributed to the room through a perforated PVC duct suspended 1.8 m (6 ft) above the crate floor. The room air was exhausted through another perforated PVC duct located underneath the floor. The room temperature was set at 21°C (70°F) to simulate the winter condition in commercial farrowing barns, which are typically controlled between 18°C (65°F) and 21°C (70°F) for the comfort of sows. Relative humidity (RH) was about 40% in the room during tests. Two enlarged crates [1.94 × 2.13 m (6.4 × 7.0 ft)] were used in the tests (fig. 1), both having woven-wire flooring for the sows and plastic slats for the creep area. One double-size mat [0.6 × 1.2 m (2 × 4 ft)] was placed in each crate on the left (crate 1) or right (crate 2) side of the sow. Single size mats [0.3 × 1.2 m (1 × 4 ft)] are normally used in commercial swine farrowing facilities. However, little scientific information is available on the actual area requirement by piglets. The use of double-size mat in this study was

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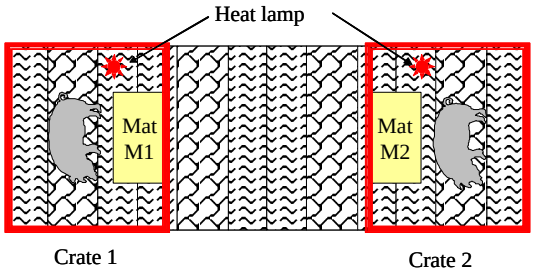


Figure 1. Schematic representation of the widened experimental farrowing crates with the dimension of 1.94 × 2.13 m (6.4 × 7.0 ft) and mat size of 0.60 × 1.2 m (2 × 4 ft) (not drawn to scale).

to allow sufficient area for the piglets to show their space needs. A 175-W heat lamp was also installed near the rear end of the sow in each creep. The use of heat lamps for 24 to 48 h is a common practice in commercial swine farrowing facilities. The lamps were suspended 76 cm (2.5 ft) above the slat floor and turned off 48 h after farrowing. The total creep area of each crate was 2.85 m^2 (30.7 ft^2) including the mat area of 0.74 m^2 (8.0 ft^2). A sow was brought into each crate about two days before the expected farrowing date for each trial. All piglets were weighed at birth and at weaning (14 to 18 days of age).

Heat mats were electrically heated with a single bank of heating elements rated at 120 W. The power input to each mat was regulated through a power controller with temperature feedback control. Embedded sensors sensed mat temperature and power input to the mat was regulated based on the sensed temperature and the setpoint. Zhang and Xin (2000) suggested an acceptable mat surface temperature range of 34°C to 43°C (93°F to 109°F) for creep heating. Two mat temperature settings of 34°C and 37°C (93°F and 99°F) were tested in this study. The 37°C setting (C37) was the highest power setting on the controller and the 34°C setting (C34) corresponded to 90% of the full power input. It should be noted that these two setpoints on the controller were different from the actual measured temperatures. The two settings resulted in mean mat surface temperatures of 33°C and 35°C (91°F and 95°F), respectively, as measured with an infrared imager (Inframetrics PM250, FLIR Systems, Inc., North Bellerica, Mass.).

The experiment ran for three months. Each of the two mat temperatures (C34 and C37) was replicated three times. The two farrowing crates were randomly assigned to the two temperature settings. Litter sizes for the three replicates of C34 test were 10, 10, and 8, and the corresponding values for C37 test were 11, 12, and 12.

A video camera (Panasonic, WV-CP410, Secaucus, N.J.) was mounted directly above the heat mat in each crate to monitor the resting behavior of piglets, and the video images were recorded using a time-lapse VCR (Panasonic, AG-6730). The tapes were then played back to determine the mat usage by counting the number of piglets lying on the mat at 15-min sampling intervals. The mat usage (MU) was calculated as the ratio of number of pigs lying on the mat (n), which was scan-sampled every 15 min, to the total number of pigs in the litter (N), i.e., MU = n/N.

The video images were also digitized using a video board (All-In Wonder, ATI Technologies Inc., Thornhill, Ont., Canada) installed in a host computer to determine the projected area (PA) of piglets on the heat mat. The Adobe Photoshop program (Adobe Systems, Inc., San Jose, Calif.) was used to calculate the number of pixels of the area occupied by piglets and the known area of the heat mat (0.74 m^2) was used as the reference to convert pixels to the actual area:

$$A_p = (P_{pig}/P_{mat})A_{mat}/n \quad (1)$$

where

A_p = average projected area of piglet on heat mat (m^2 per pig)
A_{mat} = area of heat mat (0.74 m^2)
P_{pig} = number of pixels for area occupied by piglets
P_{mat} = number of pixels for the entire heat mat area
n = number of piglets resting on the heat mat

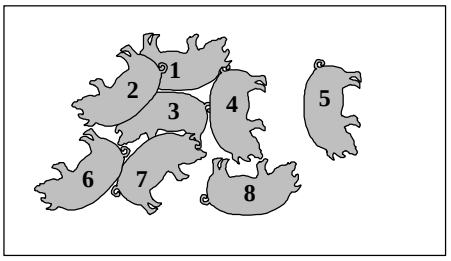
The projected areas were determined for piglets on day 1, 3, 6, 9, and 14. Six images were analyzed for each day in each test replication.

The resting patterns of piglets were determined by examining the postures of piglets resting on the heat mat. Digital images were analyzed every 4 h on day 1, 3, 6, 9, and 14 and each piglet on the images was assigned a letter to describe its posture as follows: H – huddling (overlapping); T – touching (most of body in contact with other piglets); and S – stretching (slightly or not in contact with other piglets) (fig. 2). A huddling index was calculated as the ratio of number of piglets in huddling to the total number of piglets.

Results and Discussion

The average birth weight of piglets was 1615 g (standard deviation S = 370) and 1610 g (S = 255) for tests C34 and C37, respectively (fig. 3). There was no significant (P > 0.05) difference in average daily gain (ADG) between the two test conditions: 244 g/d (S = 79) for C34 and 232 g/d (S = 42) for C37.

A difference of 2°C (3.6°F) in mat surface temperature (33°C for C34 and 35°C for C37) did not have any significant (P = 0.16) effect on the daily average mat usage (MU) (fig. 4). Piglets spent more time nursing than resting on heat mats or under heat lamps in the first 24 h. For example, the average mat and lamp usages were, respectively, 21% and 12% for the C34 test. This means that piglets spent 67% of their time nursing or lying by the sow (fig. 5). Mat usage increased sharply within the first two days and started to decrease after about the fourth day or when body weight (BW) reached 2.4 kg (5.3 lb). The peak mat usage was 61% for the two test



Pig	Posture
1	T
2	H
3	T
4	T
5	S
6	T
7	T
8	S

Total number of pigs = 8
Huddling: 1/8 = 12.5%
Touching: 5/8 = 62.5%
Stretching: 2/8 = 25%

Figure 2. Schematic of resting postures of piglets on heat mat and determination of huddling index.

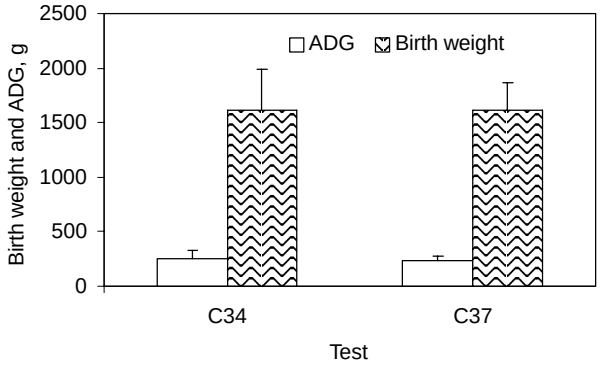


Figure 3. Average birth weight and average daily gain (ADG) of piglets for tests C34 (33°C) and C37 (35°C).

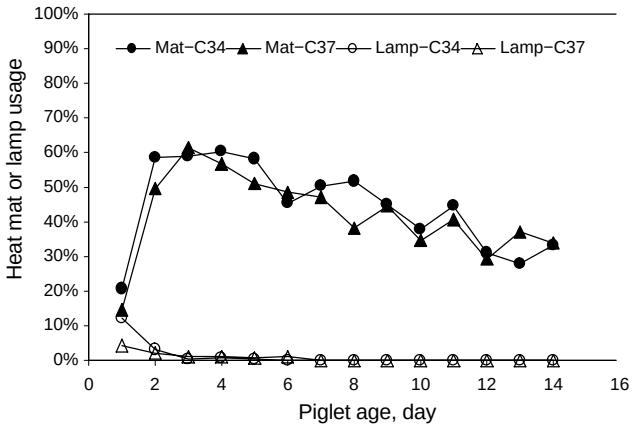


Figure 4. Daily average mat and lamp heat usage of piglets for tests C34 (33°C) and C37 (35°C).

conditions. Mat usage remained relatively constant (about 30%) after 11 d [BW reached 4.0 kg (8.8 lb)].

Piglets did not spend much time under the heat lamp when it was on for the first two days (fig. 4). For example, the average lamp usage was less than 3% on the second day for the two test conditions. This outcome was in contrast to that of another study by Zhang and Xin (2001) where piglets were observed to prefer heat lamp over heat mat for the first 2 d after birth. The difference between the current study and the earlier study was that there was a floor mat [0.6 × 1.2 m (2 × 4 ft)] under the heat lamp in the earlier study but none in the current one. The relatively large, insulated floor mat in the Zhang and Xin (2001) study might have provided a more comfortable resting surface (better heat storage and distribution) than the bare plastic slat flooring in this study. Therefore, it seems that to fully take advantage of heat lamps in creep heating, floor mats should be used under the lamps.

Heat mats provided a comfortable thermal environment to piglets, as supported by the low degree of huddling (figs. 6 and 7). On average, the huddling index was around 10% for piglets of less than six days of age. In other words, in a litter of 10 piglets, only one piglet exhibited huddling behavior and the rest of the litter were comfortable on the heat mat, as indicated by postural behavior of stretching their limbs and barely touching their littermates on the mat (fig. 7). It should be noted that the huddling index for 14-day-old piglets was higher (~20%). This was probably attributed to the limited mat area for older piglets (see discussion below on the projected area), as opposed to cold sensation.

The projected area (PA) of piglets on heat mat is an important variable in sizing heat mats, as well as an indicator of piglet comfort level. A smaller PA usually indicates that the piglet is experiencing cold sensation. It seems that the PA

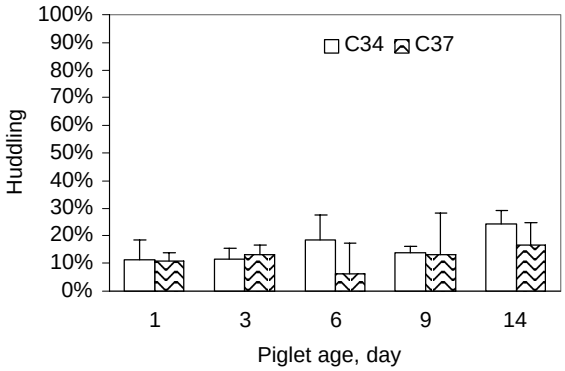


Figure 6. Huddling of piglets, data pooled from tests C34 (33°C) and C37 (35°C).

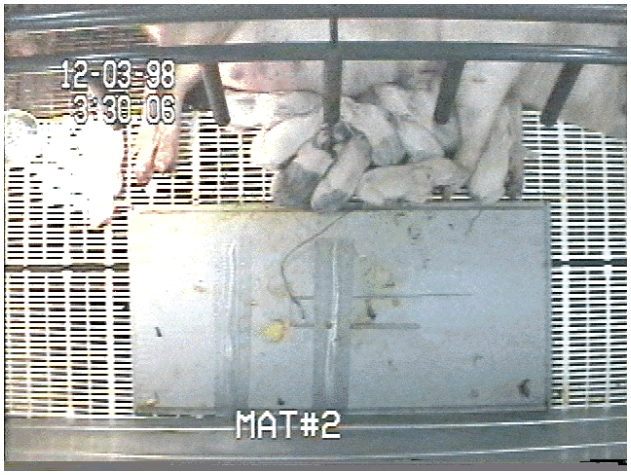


Figure 5. One-day-old piglets spent most time in nursing or lying by the sow in crate with a heat mat of 35°C (test C37).

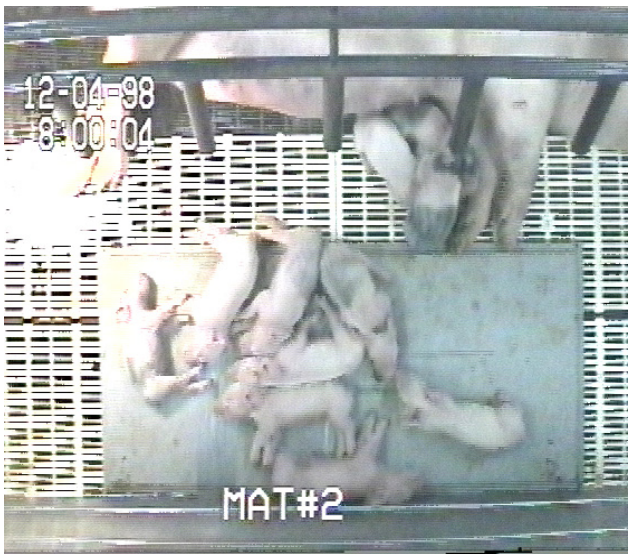


Figure 7. A resting pattern of 2-day-old piglets in crate with a heat mat of 35°C (test C37).

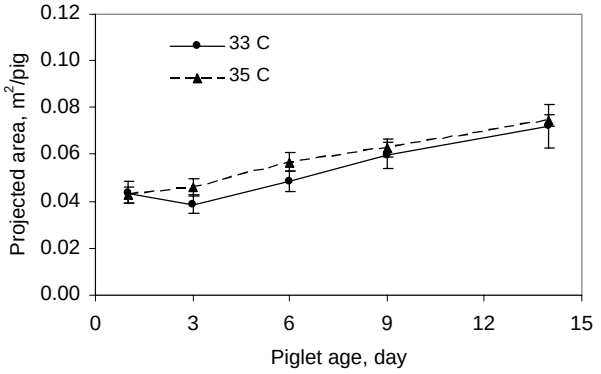


Figure 8. Projected area of piglets on heat mats at mat temperatures of 33°C and 35°C (I = 95% CI).

for mat temperature of 35°C was somewhat greater than that for 33°C (fig. 8), but the difference was not significant (P = 0.074). The PA was 0.044 m^2/pig (S = 0.010) for 1-day-old piglets and increased to 0.072 m^2/pig (S = 0.020) for 14-day-old piglets when mat temperature was 33°C. The corresponding PA values for 35°C mat temperature were 0.043 (S = 0.010) and 0.075 m^2/pig (S = 0.008), respectively. Assuming a pig to be of cylindrical shape, Boon (1981) showed that the maximum possible projected area (m^2) of a pig on floor, as related to body mass (M, kg), was:

$$A_P = 0.025M^{2/3} \quad (2)$$

The projected areas measured in this study were higher than that predicted by equation 2 (table 1), possibly due to the higher temperature of mat surface than common creep floors. Piglets stretched their limbs while resting on warm mats, resulting in somewhat a flattened cylinder shape and therefore greater projected areas. Regression analysis of the data pooled from both C34 and C37 tests produced the following equation for PA of piglets resting on heat mats (fig. 9):

$$A_P = 0.032M^{0.53} \ (R^2 = 0.87) \quad (3)$$

Heat mats of 1 × 4 ft or 0.37 m^2 (4 ft^2) are commonly used in farrowing barns in North America. From equation 3, a litter of 10 1-day-old (1.61-kg) piglets would occupy a surface area of $10 \times 0.032\ (1.61)^{0.53} = 0.41\ m^2$. If 10% of piglets are engaged in huddling (fig. 6), the area occupied by piglets is reduced to 0.37 m^2. This area of occupation seems to indicate

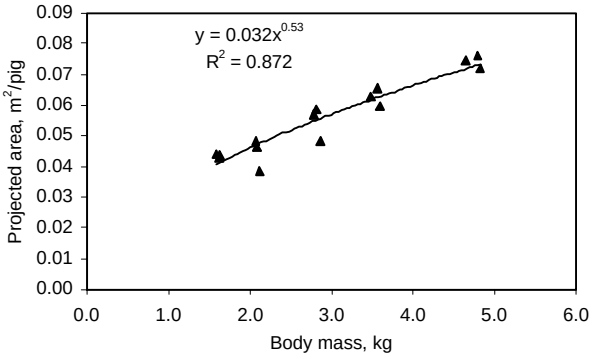


Figure 9. Projected area of piglets on heat mats, data pooled from tests C34 (33°C) and C37 (35°C).

Table 1. Comparison of measured projected area with Boon's (1981) equation.

Mass (kg)	Projected Area (m^2/pig)			
	Measured (95% CI)	Boon's Eq.	Difference	%
1.62	0.043 (0.041 − 0.046)	0.034	0.0088	20
2.09	0.044 (0.042 − 0.047)	0.041	0.0035	8
2.80	0.057 (0.054 − 0.060)	0.050	0.0075	13
3.17	0.063 (0.060 − 0.065)	0.054	0.0086	14
4.72	0.074 (0.071 − 0.078)	0.070	0.0037	5

that a single mat is barely enough to accommodate a litter of 10 piglets at birth, but it would not be large enough for older piglets. Figure 10 shows that a double mat (0.74 m^2) used in this study was not large enough for a litter of 12 piglets at nine days of age when all the piglets were simultaneously resting on the mat. However, all piglets may not use mats simultaneously at all time (fig. 7) and piglets may adjust their resting behavior to avoid crowding. To estimate the required minimum mat size, the frequency of dynamic mat usage (as shown in fig. 4) may be considered.

$$A_{req} = A_p \times N \times MU \quad (4)$$

where

A_{req} = required mat area (m^2)
N = litter size
MU = mat usage (%)

Figure 11 shows the required minimum mat areas estimated for a litter of 12 piglets. Under such circumstances (i.e., not all of piglets rest on the mat at the same time), a single mat of 0.37 m^2 (4 ft^2) would be able to accommodate the litter. However, to ensure availability of adequate mat space when all littermates need to access mat heat simultaneously, a larger mat should be used. Figure 11 indicates that piglets used the largest area on day 4. The average area of occupation was 0.046 m^2/pig for 4-day-old piglets. Therefore, a mat of $12 \times 0.046 = 0.55\ m^2$ (6 ft^2) is advisable to accommodate all 12 littermates simultaneously.

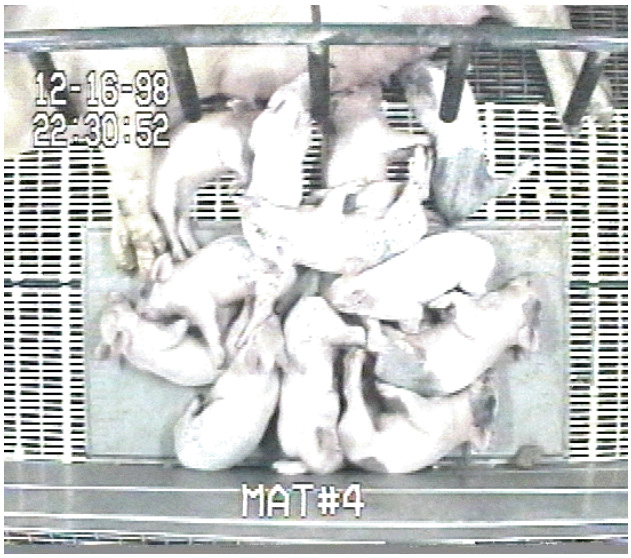


Figure 10. A resting pattern of 9-day-old piglets in crate with a heat mat of 35°C (test C37).

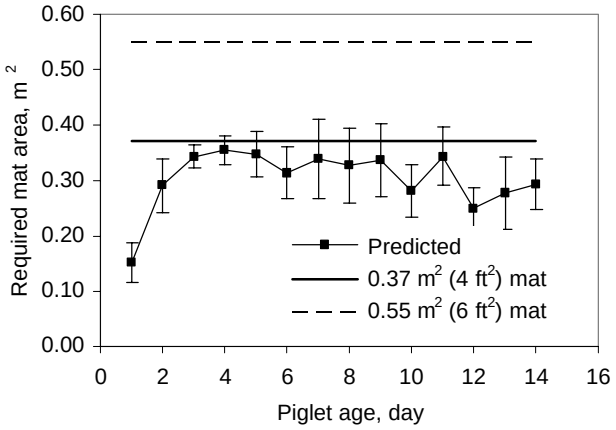


Figure 11. Mat size required by a litter of 12 piglets, estimated based on the dynamic mat use frequency as observed in this study (I = 95% CI). A mat size of 0.55 m^2 /pig (6 ft^2/pig) is advisable to ensure simultaneous accommodation of 12-piglet litters.

CONCLUSIONS

- Heat mats provided comfortable thermal environment to piglets as low degree of huddling was observed. A difference of 2°C (33°C vs. 35°C) in mat temperature did not affect the resting behavior or growth of piglets.
- Piglets spent more time nursing than resting on heat mats within the first 24 h after birth. Heat mat usage by piglets was high (60% to 50%) from day 2 to 5; it started to decrease thereafter, and remained at about 30% after 11 days of age.
- The area occupied by piglets on the mat averaged 0.044 m^2/pig (0.47 ft^2/pig) for 1-day-old piglets and 0.074 m^2/pig (0.80 ft^2/pig) for 14-day-old piglets. There was a strong correlation between the projected area of piglets on heat mats and body weight.
- Although a mat size of 0.37 m^2 (4 ft^2) could accommodate most of the space needs of 12-piglet litters due to the dynamic nature of mat usage by piglets, a larger mat size of 0.55 m^2 (6 ft^2) is advisable to ensure the well-being of piglets under unfavorable (e.g., drafty) environmental conditions when the entire litter needs to be accommodated on the mat at the same time.

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