*Arq. Bras. Med. Vet. Zootec.*, v.65, n.2, p.477-484, 2013

# Natural ventilation and surface temperature distribution of piglet crate heated floors

[*Ventilação natural e temperatura da superfície de pisos aquecidos em escamoteadores*]

A.S. *Mendes*[1], D.J. *Moura*[2], I.A. *Nääs*[2], J.R. *Bender*[3]

[1]Universidade Tecnológica Federal do Paraná – Dois Vizinhos, PR
[2]Faculdade de Engenharia Agrícola – Unicamp – Campinas, SP
[3]Universidade do Contestado – Concórdia, SC

## ABSTRACT

This research had the objective of evaluating the influence of the natural ventilation on the surface temperature distribution of heated crates. The research used six crates from a farrowing room in a commercial swine production farm located in the state of São Paulo, Brazil. Three crates were heated using a heat mat while the other three had the environment heated by incandescent light bulbs (200W) fixed on the lateral wall. The surface temperature of the crate's floor (1.55x0.55m) was registered in 36 points, distributed in 18 quadrants (0.26x0.18m) using an infrared thermometer in three different conditions of the room's natural ventilation: opened, semi-opened, and closed lateral curtain. The isotherms and the temperature distribution of the floor heat were processed using the SURFER® (1995), and the statistical analysis was done using the MINITAB® (Statistical…, 2002). It was found that the room's natural ventilation had a significant influence on crate floor surface temperature distribution. The crate with a heat mat system provided higher temperatures and led to a more homogeneous surface temperature distribution.

Keywords: thermal comfort, air velocity, farrowing, swine

## RESUMO

*O objetivo deste trabalho foi avaliar a influência da ventilação natural sobre a distribuição da temperatura na superfície de pisos aquecidos em escamoteadores. Foram avaliados seis escamoteadores da maternidade de uma granja de suínos localizada no estado de São Paulo. Dentre os escamoteadores avaliados, três deles usavam piso aquecido para o acondicionamento dos leitões, e os outros usavam lâmpadas incandescentes (200W), fixadas na parede lateral do interior do escamoteador. A temperatura da superfície do piso (1,55x0,55m) foi registrada medindo-se 36 pontos distribuídos em 18 quadrantes (0,26x0,18m), por meio de um termômetro infravermelho, em três diferentes condições de ventilação natural: com cortina lateral aberta, semiaberta e totalmente fechada. As isotermas e a distribuição da temperatura sobre o piso aquecido foram processadas usando-se o* software *SURFER®. Verificou-se que a ventilação natural teve efeito sobre a distribuição da temperatura da superfície do piso dos escamoteadores. O escamoteador aquecido com manta térmica forneceu temperaturas mais altas e distribuição mais homogênea na superfície de contato com os leitões.*

*Palavras-chave: suínos, conforto térmico, velocidade do ar, maternidade*

## INTRODUCTION

High piglet mortality is still a problem in the swine industry, and most of this mortality occurs within the first two days after farrowing (Andersen *et al*., 2005). Around 50-80% of these early losses are normally attributed to starvation and crushing by the sow (Marchant *et al*., 2001), but hypothermia might often predispose piglets to starvation and crushing (Edwards, 2002).

Recebido em 1 de setembro de 2011
Aceito em 28 de agosto de 2012
E-mail: angelica@utfpr.edu.br

Heat loss is especially critical for piglets directly after birth, as their thermoregulatory capacity is poorly developed compared to other newborn mammals which are born with fur and brown adipose tissue. When the temperature drops below the piglets' thermoneutral zone (34–36°C), piglets try to increase their heat production by means of energetically demanding muscular shivering thermogenesis (Berthon *et al*., 1994), and they try to reduce their heat loss by social and individual thermoregulation (Vasdal *et al.*, 2009). Because room temperature in the farrowing unit is normally kept within the sows' thermal comfort zone, at around 20°C (Svendsen and Svendsen, 1997), it is necessary to provide external heat sources and some sort of insulating flooring in the creep area to avoid hypothermic piglets.

Heat mats can be built with either solid material or flexible boards, embedded with heating equipment. The heat mat's heating process is accomplished by embedded electrical heating equipment or hot water circulation. A common commercial heat mat used in Brazil measures 0.3m x 1.2m, depending on crate size, consuming around 60 to 125 W/h of energy, indicating a lower consumption than that of light bulbs (175 to 250 W/h). Xin e Zhang (1999) compared the preference of piglets for light bulbs or heat mats in different environment conditions, concluding that they generally prefer heat mats.

Ventilation is one of the environmental variables that most influence thermal environments (besides humidity and temperature), hygiene (gas, odors and oxygen renewal) and confined animal's physiological response. In terms of natural ventilation management by using curtains, autumn and spring are the most changeling periods of the year, since they presents frequent changes in environmental temperature, air velocity and relative humidity (Knízková *et al*., 2002).

The internal environment of farrowing sow housing usually demonstrates a conflict of thermal requirements for the confined animals (sows and piglets) which are very distinct. Literature regarding forced ventilation systems in farrowing housing is quite complete and detailed both in theoretical and practical areas (Zhang *et al*., 1999; Lee and Phillips, 1998; Zhang *et al*., 2001; Wagenberg *et al*., 2004). However, for natural ventilation systems the literature is vague and poorly defined. This research had the objective of evaluating the influence of natural ventilation in surface heat distribution in piglet crates using two distinct heat sources.

## MATERIAL AND METHODS

This study was done in a farrowing room at a commercial swine farm, located in São Paulo State, Southern Brazil, in April 2008. Data was recorded during five consecutive days from 8:00 AM to 12:00 PM. The six crates used for the experiment had heat provided by three Technisul® heat mat surfaces, and three 200W light bulbs. The crates were in rooms with three distinct conditions: farrowing room with lateral dominant heat curtain totally opened (A), semi-opened (AF), and completely closed (F). The crates' floor temperature measurement was done manually with an Ômega® infrared thermometer 20min after turning on the surface heating, and 45 min after the curtain positioning for each studied condition (Figure 1). In total, the surface temperature (1.55x0.55m) was registered in 36 points distributed in 18 quadrants (0.26x0.18m) for each specific condition (Figure 2). The data evaluated was submitted the Covariance Analysis and the Tukey Test with Minitab 14® (Statistical…, 2002). Temperature distribution and isotherms were processed using the software Surfer® (1995).

## RESULTS AND DISCUSSION

Only on April 30th were the surface temperatures higher for the curtain condition (F) than for (A) and (AF), conditions (Figure 3). During the other days the surface temperature remained higher for condition (A) than for conditions (AF) and (F). This was due to the influence of the external environment temperature during the trial, which was 30ºC on $14^{th}$ April, 31.5 ºC on $15^{th}$ April, 26ºC on $26^{th}$ April and 21ºC on $30^{th}$ April. This fact indicates that the ventilation management in the farrowing room affects the environment of the piglets inside the crates and agrees with Vasdal *et al.* (2009).

Figure 1. Surface temperature recording with infrared thermometer in the farrowing room.

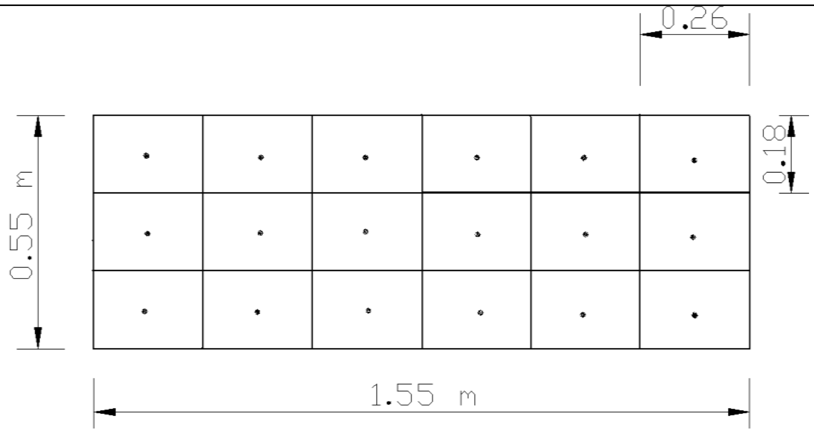



Figure 2. Representation of the surface points where temperature was recorded in the farrowing room.

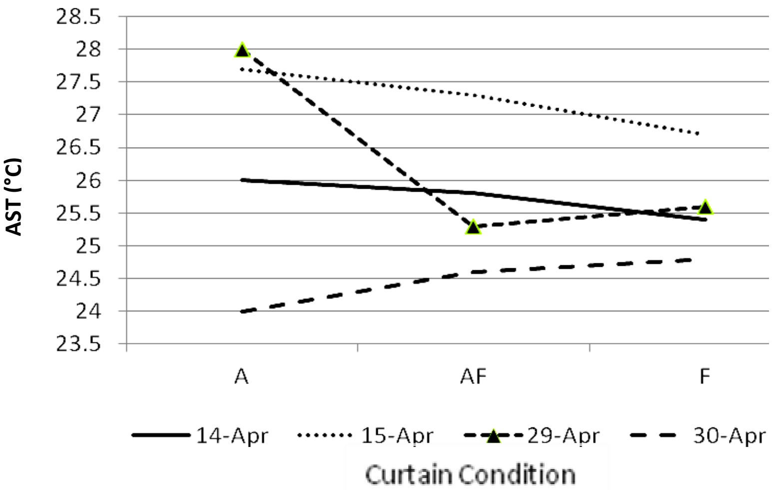



Figure 3. Different curtain conditions on the average surface temperature (AST) during the experiment in the farrowing room.

In colder days there was heat loss between the floor's surfaces and the air (Figure 4). During hotter days, on the other hand, the opposite occurred with an increase of surface temperature due to warmer circulating air. This result is in accordance with Zhang *et al*. (2001) who states that natural convection due to heat changes interferes in the temperature variation inside piglet crates affecting the environmental temperature in this location. This analysis suggested further thermal variation studies for different curtain positions and type of heating regarding the temperature during the day and natural ventilation. Next an evaluation of the data recorded in days with extreme temperatures was done.

For the coldest day, there was significant interaction between type of heating and curtain position (P-value<0.05). Figure 4 shows this interaction on surface temperature for the coldest day (April 30th), and the floor surface with a heat mat remained more stable than the light bulb heated surface. This can be seen on the results of the Tukey test in Table 1, which shows that there was no significant difference on the average of the heat mats' surface temperature with any curtain position. The same condition did not happen with the light bulb heated surfaces, which showed a significant difference between curtain positions completely closed (F) and totally opened (A), and also semi-opened (AF) and totally opened (A).

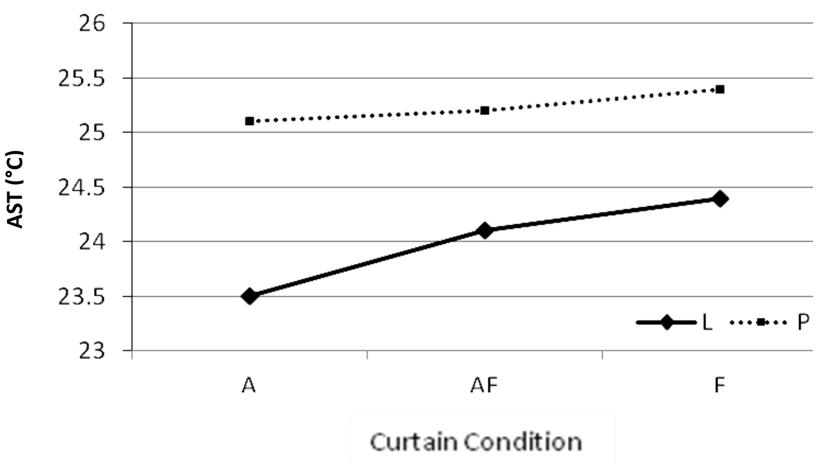



Figure 4. Interaction between different curtain positions and type of heating (L = light bulb and P = heat mat), during the coldest day, with the average surface temperature (AST).

Table 1. Surface temperature averages according the interaction of the control of natural ventilation by curtain position with types of heating

| Control of natural ventilation | Surface temperature averages (°C) |
|---|---|
| PF | 25.37a |
| PAF | 25.25a |
| PA | 25.12a |
| LF | 24.37b |
| LAF | 24.28b |
| LA | 23.52c |

Means within a column with no common letter differ by the Tukey test (n=108).

For the coldest day, there was significant interaction between type of heating and curtain position factors (P-value<0.05). In Figure 5, which shows this interaction with surface temperature during the hottest day (April 15th) a similarity between both types of heating could be observed. This can be seen in the results on Table 2, which shows a significant difference in the average of the heat mats' surface temperature with curtain position (A) and (F), and (A) and (AF). There were smaller surface temperature average differences for light bulb heated surfaces, and they only occurred with curtain positions (F) and (A).

The crate floor with a heat mat presented less heat loss to the environment when there was natural ventilation, when compared to the light bulb crate heating system during the coldest day. However, when the temperature is high during the day, the heat mat showed greater heat loss to the environment in terms of natural ventilation. This fact should not be considered a waste of energy because on hot days heating systems are not needed. Wagenberg *et al*. (2004) proved that it is possible to include boundary conditions obtained from conditions with live piglets and regarding the crate door ventilation system, the study confirmed that air distribution is inhomogeneous especially at high ventilation rates. This result can also be explained by the two distinct forms of heat transfer for both heating systems: the light bulbs provide heat through convection and radiation; the heat mats do so mainly through conduction. Similar results in heat loss in piglets crates were found by Houszka (2002) when comparing construction materials for crates.

The median test was used to evaluate the homogeneity of surface heat temperatures in both heating systems. This test considerably simplifies the information by verifying if an observation is under or above the general median. The confidence interval for homogeneity in terms of significance of 95% is -1.96<Z<1.96, which means that the quadrants with values between these intervals are significant and the surface temperature median on the quadrants exceed the inferior or superior homogeneity (Z=-1.96).

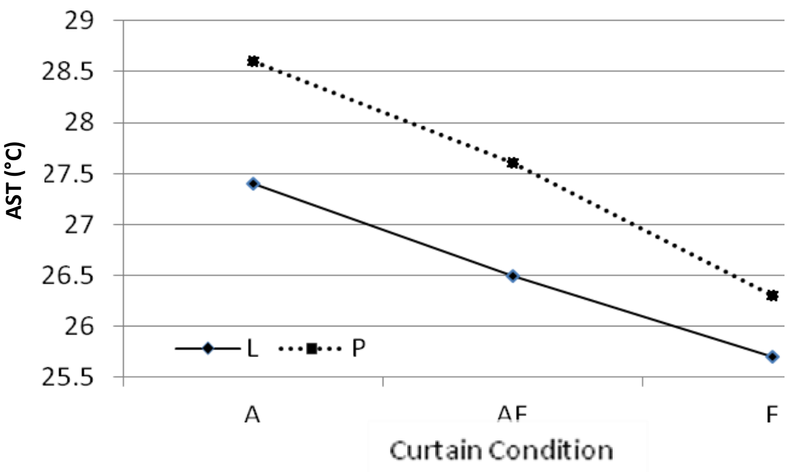



Figure 5. Curtain positions and type of heating (L = light bulb and P = heat mat), during the warmest day, with the average surface temperature (AST).

Table 2. Surface temperature averages, according the interaction of curtain position with types of heating

| Control of natural ventilation | Surface Temperature Averages (°C) |
|---|---|
| PA | 28.43a |
| PAF | 27.50b |
| PF | 26.84cb |
| LA | 27.29cb |
| LAF | 26.56cd |
| LF | 25.94d |

Means within a column with no common letter differ by the Tukey test (n=108)

The heat mat test resulted in 11 divergent points and the light bulb test resulted in 19 discrepancies, meaning that both heating systems were heterogeneous. In order to verify if there was a significant difference in the heterogeneity magnitude between both systems, the test was taken with different proportions and there was no significant heterogeneity in the distribution of surface temperature between the two heating systems, meaning that both were equally heterogeneous. The light bulb heating system presents a greater stratification on the surface temperature distribution, as seen on Figure 6 since heating was supplied from only one spot (boundary) where the area remains warmer. As for the heat mat, Figure 5 shows a surface temperature difference in certain points, which represent the presence of urine and/or feces (occurrence of latent heat loss) on the area next to the piglet's access opening. Similar results were obtained by Zhang *et al*. (1999), Zhang and Xin (2001) and Pandorfi (2002) where the same temperature profile was obtained when comparing light bulb heating (more stratified profile) with heat mats (more homogeneous profile). This stratification profile can be seen in Figure 7.

Figure 7a shows that the surface temperature of the light bulb heating varies throughout the floor surface, since one small area beneath the light bulb remains heated, while the heat decreases as the distance between the surface and light bulb gets bigger. As for the heat mats (Figure 7b) it is shown that the surface temperature also varies according to distance, not because of the location of the heat supply but due to the wind that enters through the piglet's access door.

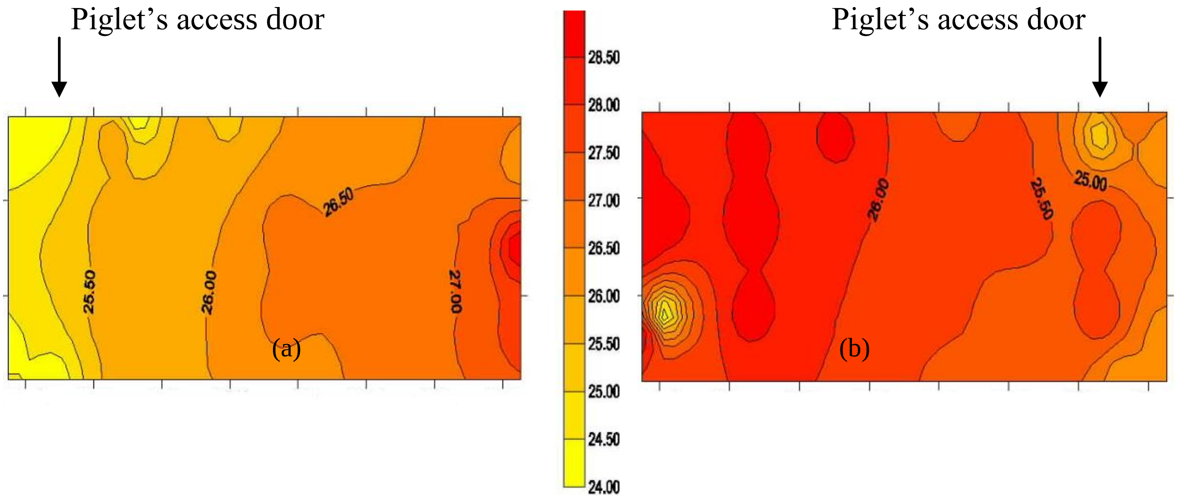
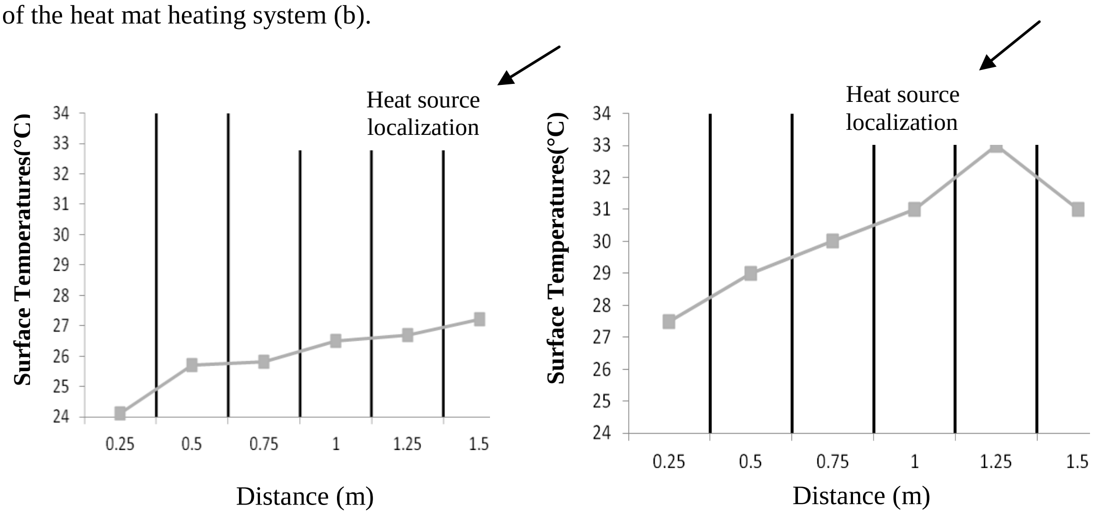



Figure 6. Isothermic representation of the light bulb heating system (a) and representation of the isotherm of the heat mat heating system (b).




(a) (b)

Figure 7. Surface temperature variation as a result of the distance to the incandecent light bulb (a) and heat mat (b).

However, it is observed that higher temperatures were provided by the heat mat system. This control of the surface temperature is very important and Vasdal *et al*. (2010) showed that piglets have a preference for high infrared temperatures when different types of heating mats were tested.

## CONCLUSIONS

Natural ventilation affected the surface temperature of piglet crates heated both by heat mats and by light bulbs. The magnitude of this effect is influenced not only by the external temperature but also by natural ventilation due to the adopted curtain position. The crate with a heat mat system provided higher temperatures and led to a more homogeneous surface temperature distribution, which provides a more desirable crate environmental condition regardless of the curtain position. Since the crate heating systems in the farrowing room were highly affected by natural ventilation due to different curtain positions, an accurate control of natural ventilation based on the adopted crate heating system is needed in order to provide the piglets with a more balanced environment.

## REFERENCES

ANDERSEN, I.L.; BERG, S.; BØE, K.E. Crushing of piglets by the mother sow (Sus scrofa) − purely accidental or a poor mother? *Appl. Anim. Behav. Sci.,* v.93, p.229-243, 2005.

BERTHON, D.; HERPIN, P.; LE DIVIDICH, J.L. Shivering thermogenesis in the neonatal pig. *J. Thermal Biol.*, v.19, p.413-418, 1994.

EDWARDS, S.A. Perinatal mortality in the pig: environmental or physiological solutions? *Livest. Prod. Sci.,* v.78, p.3-12, 2002.

HOUSZKA, H.M. Thermal conditions within a piglet creep area with different cover constructions and different surface of cover materials. *The CIGR Journal of Scientific Research and Development*, v.4, p.1-8, 2002.

KNÍZKOVÁ, I.; KUNE, P.; KOUBKOVÁ, M. *et al.* Evaluation of naturally ventiled dairy barn management by a thermographic method. *Livest. Product. Sci.*, v.77, p.349-353, 2002.

LEE, D.H.K.; PHILLIPS, R.W. Assessment of the adaptability of livestock to climatic stress. *J. Anim. Sci.,* v.7, p.391-425, 1998.

MARCHANT, J.N.; BROOM, D.M.; CORNING, S. The influence of sow behaviour on piglet mortality due to crushing in an open farrowing system. *Anim. Sci.,* v.72, p.19-28, 2001.

STATISTICAL software for windows: release version 14. e-academy: Minitab, 2002.

PANDORFI, H. *Avaliação do comportamento de leitões em diferentes sistemas de aquecimento por meio da análise de imagem e identificação eletrônica*. 2002. 89f. Dissertação (Mestrado). Faculdade de Agronomia, ESALQ/USP, Piracicaba, SP.

SURFER version 6.01. Golden: Golden Software, 1995.

SVENDSEN, J.; SVENDSEN, L.S. Intensive (commercial) systems for breeding sows and piglets to weaning. *Livest. Prod. Sci.,* v.49, p.165-179, 1997.

VASDAL, G.; WHEELER, E.F.; BØE, K.E. Effect of infrared temperature on thermoregulatory behaviour in suckling piglets. *Animal,* v.3, p.1449-1454, 2009.

VASDAL, G.; MØGEDAL, I.; BØE, K.E. *et al.* Piglet preference for infrared temperature and flooring. *Appl. Anim. Behav. Sci.*, v.122, p.92-97, 2010.

WAGENBERG, A. VAN; BJERG, B.; BOT, G. Measurement and simulation of climatic conditions in the animal occupied zone in a door ventilated room for piglets. The CIGR Journal of Scientific Research and Development, Manuscript BC 03 020, v.1, p.1-19, 2004.

XIN, H.; ZHANG, Q. Preference for lamp or mat heat by piglets at cool and warm ambient temperatures with low to high drafts. *Appl. Eng. Agricult.,* v.5, p.547-551, 1999.

ZHANG, G.; MORSING, S.; STROM, J.S.; RAVN, P. Air motion temperature distribution within covered pig creep zones in rooms. In: INTERNATIONAL SYMPOSIUM OF ASAE, 6., 2001,Louisville. **Proceedings**. Louisville: ASAE, 2001. p.262-269.

ZHANG, G.; SVIDT, K.; BJERG, B.; MORSING, S. Buoyant flow generated by thermal convection of a simulated pig. *Transactions of the ASAE*, v.4, p.1113-1120, 1999.

ZHANG, Q.; XIN, H. Responses of piglets to creep heat type and location in farrowing crate. *Appl. Eng. Agricult.*, v.17, p.515-519, 2001.