

Thermo-acoustic environment of a pig farm facility with different superimposed bed materials

Francine Aparecida Sousa ▪ Alessandro Torres Campos ▪
Daiane Cecchin ▪ Pedro Ivo Sodr  Amaral ▪ Rony Antonio Ferreira ▪
Jaqueline de Oliveira Castro ▪ Soraia Viana Ferreira

FA Sousa (Corresponding author) ▪ **AT Campos** ▪ **PIS Amaral** ▪ **RA Ferreira** ▪ **JO Castro** ▪ **SV Ferreira**
Universidade Federal de Lavras (UFLA), MG, Brazil.
e-mail: francine.sousa@ymail.com

D Cecchin
Universidade Federal Fluminense (UFF), RJ, Brazil

Received: December 24, 2016 ▪ Revised: February 20, 2017 ▪ Accepted: March 22, 2017

Abstract The objective of this work was to compare different bedding materials in swine production systems by evaluating noise and thermal environment indexes. The experiment was performed during June and July, in the finishing phase, in a pig farm facility using superimposed beds. Three treatments were compared: superimposed beds comprised of shavings + sugarcane bagasse (S + B), superimposed bed comprised of sugarcane bagasse (BAG) and superimposed bed comprised of shavings (SHA); there was a concrete floor underneath all beds. Thermal comfort was evaluated by means of the black globe temperature (BGTI), temperature humidity index (THI), thermal radiation charge (TRC) and enthalpy (h) of the environment. The average noise level (dB) was also calculated. Significant differences between the BGHI means were observed between the evaluated treatments. The highest BGHI values occurred for treatment (S + B) in most time periods in relation to the other treatments. The lowest BGHI values were observed in the morning and evening, while the highest values occurred between 11:00 am and 03:00 pm. There was no significant difference between the treatments for the enthalpy values. The highest noise values were observed in treatment (SHA). However, in all treatments, noise remained below the levels recommended by the norm (NR-15). The system with superimposed beds comprised by shavings provided highest thermal comfort for the animals in the finishing phase.

Keywords: thermal comfort, noise, installations for swine production, rural constructions, ambience

Introduction

Brazilian pig farms are increasingly aiming to incorporate animal welfare, in addition to comply with environmental regulations (Tin co et al 2007). In tropical conditions, thermal discomfort of farm animals is frequent and represents one of the main problems of modern swine farming,

especially in terms of meeting export demands (Silva et al 2007).

For a number of years, efforts to optimize animal production have focused on management, sanitation, genetics, and nutrition (Rocha et al 2012). However, currently, advances in these areas are limited by environmental factors, mainly by the thermal conditions the animals are being subjected to (Alvarenga et al 2011).

The identification of the climatic factors that directly influence animal performance is crucial for the development and execution of mitigation measures to ensure economic viability (Barnett et al 2001; Bloemhof et al 2008; Nazareno et al 2012; Ver ssimo et al 2009). According to previous studies, high ambient temperatures considerably affect pig performance (Kiefer et al 2009; Rocha et al 2012).

Therefore, recent studies have focused on the thermal environment in animal farming (Lima et al 2011). In confined breeding systems, energetic losses of the animals are smaller; however, natural behavior is restricted, thereby affecting productive and reproductive performance (Pandorfi et al 2007; Pandorfi et al 2008; Nazareno et al 2009).

The use of superimposed beds on the floor as an alternative to traditional concrete flooring provides higher environmental quality and is therefore an interesting option in pig breeding, esp. in the growth and finishing stages (Corr ea et al 2000). Performance in such systems is comparable with that in conventional confined systems, also in terms of a rapid achievement of slaughter weight (Guimar es et al 2011). According Oliveira and Higarashi (2004), this system is characterized by larger pens than used in common confined systems, where the animals remain on a substrate bed. In this case, production generated by the binomial "animal + bed" must be considered (Cordeiro et al 2007). Various materials can be used as substrate for superimposed beds. The choice of a particular product should be based on factors such as ease of obtaining, handling, and reusing the bed when removing it from the premises and the environmental comfort they offer.

The thermal environment inside the facilities is vitally important for the success of pig farming. The comfort or discomfort can be evaluated by the black globe humidity index (BGHI), which includes air temperature (Tair), relative humidity (RH), thermal radiation, and air speed (AS) (Vieira et al. 2010). Here, the combination “Tair – RH” is the main factor influencing thermal comfort (Souza et al 2010). According to Rossi et al (2012), in the evaluation of thermal comfort, the factor enthalpy, moist air energy per unit dry mass of air, is the most useful property in the quantification of psychrometric processes that involve thermal changes.

In this context, the quantification of environmental discomfort and animal welfare in an intensive production environment has been highlighted as an important theme among researchers in the area (Nääs et al 2008; Kiefer et al 2010). Among the different evaluation mechanisms, studies of the noise level of a group of animals are being increasingly performed (Silva-Miranda et al 2012).

Noise can be easily measured with the aid of decibel meters (Borges 2008; Tolon et al 2010), and the levels vary according to the environmental situations to which the animals are submitted, thereby indicating animal life quality (Sampaio et al 2007; Nääs et al 2008; Tolon et al 2010). Modern noise analysis techniques allow the discrimination, analysis, and classification of specific noises, making noise level an interesting indicator of the well-being conditions of a group or an individual animal (Silva et al 2007).

In view of the above, the objective of this work was to compare pig breeding systems using superimposed beds comprised of i: sugarcane bagasse (BAG), ii; shavings (SHA), and iii: shavings + sugarcane bagasse (S + B). Thermal environment in the pig finishing phase was evaluated as a function of air temperature and humidity, measuring black globe and humidity index (BGHI), radiant thermal load (RTL), and enthalpy (H) in addition to evaluating noise levels.

Materials and Methods

The experiment was carried out in June and July 2013, at the finishing lots of the swine production facility of the Instituto Federal do Sudeste de Minas Gerais, Campus Rio Pomba – MG. The place is located at an altitude of 434 m, with the geographic coordinates 21° 16' 45" S and 43° 10' 30" W. The climate of the region, according to the classification of Köppen, is Cwa (hot and rainy, with a distinct dry season in winter and hot summers).

We compared three types of superimposed beds: i: sugarcane bagasse (BAG), ii; shavings (SHA), and iii; shavings+sugarcane bagasse (S+B) at a ratio of 1:1. The pens had concrete floors underneath the beds and were equipped with a masonry feeder and two drinking fountains. (Fig. 1).



Figure 1 Three types of superimposed beds: i; sugarcane bagasse (BAG), ii; shavings (SHA), and iii; shavings+sugarcane bagasse (S+B).

The installation was oriented in an east-west direction, with a ceiling height of 3.30 m, a two-story roof covered with cement-asbestos tiles, masonry walls, internal and external masonry partitions with a height of 1 m, and a concrete floor covered with superimposed bed. Three stalls were used, with an average area of 30 m², arranged side by side. The first one contained beds of sugarcane bagasse + shavings, the second one beds of sugarcane bagasse, and the third one beds of shavings (Fig. 2). Density was 1.70 m² per pig (including the elevated platform with the waterers and feeders), with 17 landrace animals per bay. Average animal weight was 64.8 ± 6.7 kg. The beds had a depth of 0.50 m in all treatments. Feeding was performed manually three times a day.

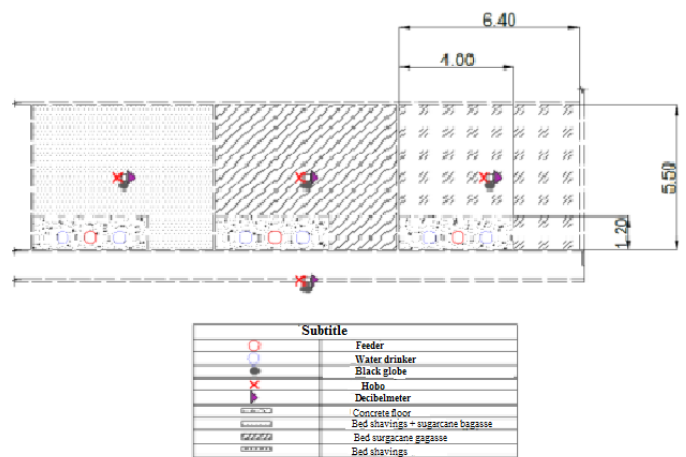


Figure 2 Position of collection devices in pens –containing beds composed of 1: shavings + sugarcane bagasse (S + B), 2: sugarcane bagasse (BAG), 3; shavings (SHA).

Air temperature, relative humidity, and black globe temperature were recorded in intervals of 5 min inside the pens and in the outside area, using Hobo dataloggers, model U12-013, with an accuracy of ± 0.5°C. For determination of black

globe temperature, sensors of the dataloggers were inserted into a black globe. Air velocity was recorded using a digital propeller anemometer (Thermo anemometer®) with an accuracy of ± 3.0% of the reading. To assess ambient thermal comfort, the dataloggers were positioned within the premises at a height of 1.20 m from the floor (Sampaio et al 2004).

To characterize the environment inside and outside of the facilities, we determined dry bulb temperature (DBT), relative air humidity (RH), black globe temperature (Tbg°C), and enthalpy. The BGHI was used to evaluate the thermal environment, in addition to indirectly quantifying the effects of air velocity and radiation, via the following equation:

$$BGHI = tbg + 0.36 tdp - 330.08,$$

where tbg is the black globe temperature (K) and tdp is the dew point temperature (K).

Thermal radiation charge (TRC) was calculated according to the equation proposed by Esmay (1974):

$$TRC = \sigma(ART)^4,$$

where TRC is the thermal radiation charge (W m⁻²), σ is the constant of Stefan-Boltzman (5,67.10-8 W m⁻² K⁻⁴), and ART is the average radiant temperature (K). Here, ART it is the uniform temperature of a radiant black enclosure (Bond et al 1961) and was obtained using Equation 3:

$$ART = 100 \times \left[2.51 \times (As)^{1/2} (Tbg - Tair) + (Tbg/1000)^4 \right]^{1/4}$$

where ART is the average radiant temperature (K), As is the air speed (m s⁻¹), and Tair is the air temperature (K).

The enthalpy (h) of the environment was calculated according to the equation below, proposed by Albright (1990):

$$h = 1.006 \times Tdb + W(2501 + 1.805 \times Tdb)$$

where h is the enthalpy (kJ kg of dry air⁻¹), Tdb is the dry bulb temperature (°C), and W is the mixing ratio (kg water vapor kg dry air⁻¹).

$$W = (0.622 \times ea) / (Patm - ea)$$

where ea is the current water vapor pressure (kPa) and Patm is the atmospheric pressure (kPa).

For the statistical analysis, a subdivided plots scheme was chosen for thermal environment data (BGTI, TRC, and

enthalpy), in which the plots represented the three different superimposed beds the subplots the times (1 to 24 hours), in a randomized block design (experimental days). Replicates were the days of collection, 15 days. The data were submitted to analysis of variance and the means compared by the Scott-Knott test at 5% significance. Statistical analyses were performed using the Sisvar program (Ferreira 2008).

For noise level measurements (dB), an SL-130 mark (Sound Level Meter) was used, accuracy of ± 1.5 dB; measurements were performed at the following times: 09 am, 11:30 am, 02 pm, and 04:30 pm, during a period of 15 days, according to the recommendations of Sampaio et al (2005). Based on these results, boxplot graphs were composed considering the values observed at the height of the animals and using the statistical package Minitab® 16.1.0.

Results and Discussion

Bed type influenced TRC only at 04:30 pm, where the treatment S+B had significantly higher TRC values (P < 0.05) compared to the other treatments (Table 1). In terms of mean values, a similar behavior was observed for TRC and BGTI; the higher values of TRC and BGHI may have been a result of the mixed bedding material, which led to higher fermentation rates and lower evaporation of the colloidal water contained in the material, thus raising the temperature in the environment.

Sampaio et al (2004), evaluating an installation in the finishing phase, observed that the TRC values varied more strongly between 02:00 pm and 06 pm. In the present study, the hourly means found for TRC followed the same pattern as that found by Camerini et al (2009), who observed an increase in TRC values throughout the morning, with a decline after 02:00 h. When the averages were compared to the comfort values, for 450 W m⁻², as described by Baêta and Souza (2010), the measurements at 11:30 am and 02:00 pm were particularly high, indicating increased thermal discomfort.

At the same time, there is evidence of more critical climatic conditions in the environment with this bedding material, since the BGHI suffers the effect of the globe temperature.

In the present study, BGHI values obtained at 02:00 pm, in all treatments, were above the thermal comfort amplitude for pigs, which is 72 (Sampaio et al 2004).

Based on the BGHI values in all treatments, the animals were subjected to temperatures above those of the comfort zone. However, this situation cannot be characterized as stress, since the average BGHI value was 71.66. According to Kiefer et al (2009), BGHI values close to 81.10 represent high heat stress for finishing pigs.

Table 1 Black Globe Temperature and Humidity Index (BGTI), enthalpy (h), and Thermal Radiation Charge (TRC) in relation to bedding material and measurement time in a pig finishing unit.

Index	Bed ¹	Time				Means
		09:00 am	11:30 am	02:00 pm	04:30 pm	

BGTI	S+B	67,6 ^a	72,8 ^a	74,4 ^a	71,8 ^a	71,7 ^a
	BAG	67,2 ^a	72,8 ^a	74,4 ^a	71,1 ^a	71,4 ^b
	SHA	67,1 ^a	72,9 ^a	74,4 ^a	71,1 ^a	71,3 ^b
Enthalpy	S+B	50,7 ^a	58,4 ^a	59,2 ^a	59,1 ^a	56,9 ^a
	BAG	51,4 ^a	58,4 ^a	59,4 ^a	59,0 ^a	57,0 ^a
	SHA	51,1 ^a	58,4 ^a	59,2 ^a	58,7 ^a	56,8 ^a
TRC	S+B	425,1 ^a	450,9 ^a	460,9 ^a	441,1 ^a	444,5 ^a
	BAG	420,8 ^a	453,1 ^a	460,9 ^a	435,6 ^b	442,6 ^b
	SHA	421,3 ^a	453,2 ^a	460,7 ^a	435,4 ^b	442,7 ^b

*Means followed by different letters within a column are significantly different by Scott-Knott test. 1superimposed bed comprised of shavings+sugarcane bagasse (S+B), superimposed bed comprised of sugarcane bagasse (BAG), and superimposed bed comprised of shavings (SHA).

In a study carried out by Cordeiro et al (2007), BGHI values differed between breeding systems (shaving bed, rice bark bed, and concrete floor) and between observation hours. There was also a gradual increase in the BGHI values during the growth phases, which is related to the natural elevation of the local ambient temperature and the higher production and the heat release by the animals as they grew.

In studies by Turco et al (1998) and Campos et al (2008), the upper limit of thermal comfort for finishing pigs, based on BGTI, was 72. In the breeding systems evaluated, at warmer hours (02:00 pm), the animals suffered thermal discomfort; this pattern has also been observed in similar studies (Tinôco et al 2007). Sampaio et al (2004), in a study on finishing pigs, observed BGHI values of 72.5 within the facility at 12:00 am and 74.8 at 04:00 pm, which were significantly higher than the values in the present study.

The lowest BGTI values in our study were observed in the early morning and late afternoon, while the highest values occurred between 11:00 am and 03:00 pm; these findings are agreement with the results of Tolon and Nääs (2005). Similarly, Amancio et al (2013) observed elevated BGHI values throughout the day, with maximum values at 3:00 pm (81.12) and a decrease thereafter. The temperature and type of bed used may influence the exchange of animal-environment heat, thus modifying the critical temperatures of the animals.

Furtado et al (2012), evaluating nursery and finishing facilities in a conventional system, obtained values of BGHI above the recommended level, both in the rainy and in the dry season. According to the authors, at the hottest time of the day, the animals were panting, indicating thermal discomfort and highlighting the need to improve the bioclimatic conditions of such amenities.

When assessing the effects of air temperature on behavior, physiological responses, and performance of pigs in the growth phase, Kiefer et al (2009) observed that heat stress causes behavioral disturbances, negatively affects performance (feed intake, weight gain, feed conversion), and alters the physiology of pigs.

The enthalpy values were similar between the evaluated systems, with no significant difference between the

treatments, being slightly below the range established for the index (Table 1). According to Moura (1999), the desired enthalpy value for the growth phase is 60.44 to 68.62 kJ kg of dry air-1. This way, all treatments, at all times evaluated, presented enthalpy values below the recommended limit. Sarubbi et al (2012), in an installation with clay tile roof (69.24 kJ kg of dry air-1) and an installation with a roof of asbestos cement tiles (73.45 kJ kg of dry air-1), that enthalpy values were higher than the recommended range. In the present study, however, enthalpy values were lower than the tolerated values.

The approximations of the recommended enthalpy values were calculated based on the comfort conditions of the animals. The enthalpy values express the amount of energy contained in a mixture of dry air and water vapor, thus influencing the thermal changes between the animal and the medium.

Figure 3 and Table 2 show the values related to the noise levels in the three evaluated treatments. The results indicate that there was no significant difference in noise levels between the different measurement times. However, noise levels differed between the treatments across the whole study period and were significantly higher in the SHA treatment ($P < 0.05$) than in the BAG treatment.

Despite these observed differences, all treatments were within the range of noise emission recommended by the NR-15 standard of 85 dB. In a study carried out by Sampaio et al (2005), the noise generated by the animals was, on average, 73 dB, which is within the limits of tolerance.

The results presented here corroborate those obtained by Sampaio et al (2007) who, in an intensive pig production environment, measured noise levels of 65 dB in nursery facilities. Studying animals in the maternity phase, Castro et al (2013) also obtained mean values of the maximum recommended value for swine breeding, which is up to 85 dB (Moura and Sarubbi 2009). However, in none of the previous studies, an overlap bed was used. Silva-Miranda et al (2012) point out that highest noise levels were associated with thermal discomfort. However, these authors reported higher noise levels than those observed in our study.

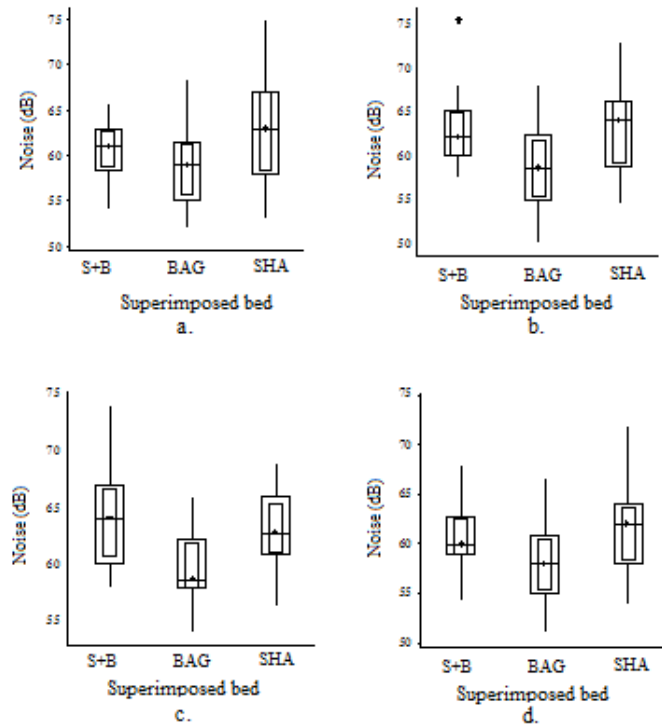


Figure 3 Median noise level values at different times (a: 09:00 am; b: 11:30 am; c: 02:00 pm and d: 04:30 pm) in pens composed of three different bedding materials: i; sugarcane bagasse (BAG), ii; shavings (SHA), and iii; shavings + sugarcane bagasse (S + B).

Silva et al (2007), in studies on noise emitted by pigs, did not find a correlation between the environmental variables and the noise levels emitted by the animals in an intensive production environment.

The Department of Environment, Food and Rural Affairs (DEFRA) of the United Kingdom has created the "Code of Recommendation for Welfare in Pig Breeding", stating that sound pressure values above 85 dB should be avoided as well as exposure of animals to constant noise

(DEFRA 2003). According to Tolon et al (2010), at such a high sound pressure level (85 dB), the animals may be unable to develop natural behavior.

In a similar study, evaluating the effects of seasonality on noise levels in pig nursery, Baracho et al (2008) observed that noise levels were not affected by the season, but may fluctuate during the course of the day due to several factors, such as hot periods and feeding times.

Table 2 Medians of the confidence interval (CI = 95%) for noise level (dB) in relation to bed material and collection times in a pig finishing unit in pens composed of three different bedding materials: i; sugarcane bagasse (BAG), ii; shavings (SHA), and iii; shavings+sugarcane bagasse (S+B).

Bed	Level Noise (dB)				Median
	Time				
	09:00 am	11:30 am	02:00 pm	04:30 pm	
S+B	61 (58,8-62,7)	62 (60-64,9)	64 (60,7-66,6)	60 (59-62,5)	62 (60-62,5)
BAG	59 (55,7-61,4)	59 (55,4-61,8)	59 (58-61,9)	58 (55,4-60,6)	59 (58-60,1)
SHA	63 (58,4-67)	64 (59,2-66,1)	63 (60,9-65,3)	62 (58,5-63,6)	63 (61-64)

Conclusions

The highest values of BGHI were observed in the treatment using superimposed bedding + bagasse. The enthalpy values did not differ significantly between treatments. Thermal radiation charge at 04:30 pm, in the pen composed by shavings + bagasse, was relatively high

compared to the other treatments. Based on the thermal data, we could verify that all treatments provide thermal comfort for pigs in the finishing phase. Noise levels in all evaluated treatments remained within the limits recommended by the NR-15, considering the environment acceptable for the rearing of pigs.

Acknowledgements

We thank the National Council for Scientific and Technological Development (CNPq) and the Minas Gerais Research Support Foundation (FAPEMIG) for financial support. We also thank the Coordination for the Improvement of Higher Education Personnel (CAPES) for providing a doctoral scholarship and the Instituto Federal do Sudeste de Minas Gerais, Campus Rio Pomba – MG for supplying the facilities.

References

- Albright LD (1990) Environment control for animals and plants. Michigan: American Society of Agricultural Engineers (ASAE), 4, 453p.
- Alvarenga ALN, Zangeronimo MG, Oberlender G, Murgas LDS (2011) Aspectos reprodutivos e estresse na espécie suína. (Boletim Técnico) nº 86, p.1- 40. Lavras: UFLA.
- Amancio D, Furtado DA, Nascimento JWB, L Santos, LFD. (2013) Avaliação da qualidade do ar e ambiente térmico em maternidade suinícola no semiárido paraibano. *Revista Educação Agrícola Superior* 28:10-14.
- Baêta FC, Souza CF (2010) *Ambiência em edificações rurais: Conforto animal*. 2ª ed. Viçosa: UFV. 246p.
- Barnett JL, Hemsworth PH, Cronin GM, Jongman EC, Hutson GD (2001) A review of the welfare issues for sows and piglets in relation to housing. *Australian Journal of Agricultural Research* 52:1-28.
- Barracho MS, Tolon YB, Nääs IA, Rojas M (2008) Sazonalidade da ambiência térmica, aérea e acústica em creche e terminação de suínos. *Revista Brasileira de Engenharia de Biosistemas* 2:201-212.
- Bloemhof, S.; Van Der Waaij EH, Merks JWM, Knol EF (2014) Sow line differences in heat stress tolerance expressed in reproductive performance traits. *Journal of Animal Science* 86:3330-3337.
- Bond TE, Kelly CF, Garret WN, Hahn L (1961) Evaluation of materials for livestock shades. *Califórnia Agriculture* 15:7-8.
- Borges G (2008) Utilização da pressão sonora (ruído) como indicativo de bem-estar animal na produção industrial de suínos. 137f. Dissertação (Mestrado em Agronomia) - Escola Superior de Agricultura Luiz Queiroz, Universidade de São Paulo, SP.
- Brasil (1978) Ministério do Trabalho e Emprego. Portaria 3.214 de julho 1978. Normas regulamentadoras de segurança e saúde no trabalho - NR-15: atividades e operações insalubres. Brasília
- Camerini NL, Nascimento JWB, Fook MVL, Soares EA, Silva FAS (2009) Análise de variáveis ambientais em modelos reduzidos de instalações agropecuárias com forro de resíduo de EVA. *Revista Eletrônica de Materiais e Processos* 4:40-47.
- Campos JA, Tinôco IFF, Baêta FC, Silva, JN, Carvalho CS, Mauri, AL (2008) Ambiente térmico e desempenho de suínos em dois modelos de maternidade e creche. *Revista Ceres* 55:187-193.
- Castro JO, Campos AT, Ferreira RA, Yanagi Junior T, Tadeu HC (2013) Uso de ardósia na construção de celas de maternidade para suínos: II - ambiente térmico e avaliação dos ruídos. *Engenharia Agrícola* 33:37-45.
- Cordeiro MB, Tinôco IFF, Oliveira PAV, Guimarães MCC, Baêta FC, Silva JN (2007) Efeito de sistemas de criação no conforto térmico ambiente e no desempenho produtivo de suínos na primavera. *Revista Brasileira de Zootecnia* 35:1597-1602.
- Corrêa EK, Perdomo CC, Jacondino IF (2000) Condicionamento ambiental e desempenho de suínos em crescimento e terminação criados sobre piso com leito de cama. *Revista Brasileira de Zootecnia* 29:2072-2079.
- DEFRA (Department for Environment, Food & Rural Affairs) (2003) Code of Recommendations for the Welfare of Livestock: Pigs. United Kingdom. Disponível em: <[http:// tinyurl.com/4cwen45](http://tinyurl.com/4cwen45)>. Online. Acesso em: 21 dez. 2013.
- Esmay ML (1974) *Principles of animal environment*. 2.ed. Westport: AVI Publishing Company, 325p.
- Ferreira DF (2008) SISVAR: um programa para análises e ensino de estatística. *Revista Symposium* 6:36-41.
- Furtado DA, Amancio D, Do Nascimento JWB, Gomes JP, Silva RC (2012) Thermal performance and concentration of gases in facilities for pigs in Semiarid Region from State of Paraíba-Brazil. *Engenharia Agrícola* 32:30-37.
- Guimarães GG, Murata LS, Mcmanus AC, Santana AP, Reckziegel GCB, Amâncio AS, Filho RMJ, Sobrinho AJF (2011) Desempenho de suínos de dois cruzamentos de linhagens comerciais criados em cama sobreposta. *Archivos de zootecnia* 60:11-18.
- Kiefer C, Meignen BCG, Sanches JF, Carrijo AS (2009) Resposta de suínos em crescimento mantidos em diferentes temperaturas. *Archivos de Zootecnia* 58:55-64.
- Kiefer C, Moura MS, Silva EA, Santos AP, Silva CM, Luz MF, Nantes CL (2010) Respostas de suínos em terminação mantidos em diferentes ambientes térmicos. *Revista Brasileira de Saúde Produção Animal* 11:496-504.
- Lima AL, Oliveira RFM, Donzele JL, Fernandes HC, Campos PHRF, Antunes MVL (2011) Resfriamento do piso da maternidade para porcas em lactação no verão. *Revista Brasileira de Zootecnia* 40:804-811.
- Minitab (1995) *A beginner's guide to MINITAB statistics software*. Pennsylvania: State College, 562 p.
- Moura DJ, Sarubi J (2009) Interação entre ambiência e produtividade na suinocultura industrial: realidade brasileira e as exigências internacionais. *Suinocultura Industrial, Campinas*, p.28-33.
- Moura DJ (1999) Ventilação na suinocultura. In: SILVA I.J.O. *Ambiência e qualidade na produção industrial de suínos*. Piracicaba: FEALQ. p.149-179.
- Nääs IA, Campos LSL, Baracho MS, Tolon YB (2008) Uso das redes neurais artificiais na identificação de vocalização de suínos. *Engenharia Agrícola* 28:204-216.
- Nazareno AC, Pandorfi H, Almeida GLP, Giongo PR, Pedrosa EMR, Guiselini C (2009) Avaliação do conforto térmico e desempenho de frangos de corte sob regime de criação diferenciado. *Revista Brasileira de Engenharia Agrícola e Ambiental* 13:802-808.
- Nazareno AC, Silva IJO, Nunes MLA, Castro AC, Miranda KOS,

- Trabachini A (2012) Caracterização bioclimática de sistemas ao ar livre e confinado para a criação de matrizes suínas gestantes. *Revista Brasileira de Engenharia Agrícola e Ambiental* 16:314–319.
- Oliveira PAV, Higarashi MM (2004) Produção de suínos em sistema de cama sobreposta. Em: P.A.V. Oliveira (Ed.) *Tecnologias para o manejo de resíduos na produção de suínos. Manual de Boas Práticas. Embrapa Suínos e Aves*. p.57-67.
- Pandorf H, Silva IJO, Guiselini C, Piedade SMS (2007) Uso da lógica fuzzy na caracterização do ambiente produtivo para matrizes gestantes. *Engenharia Agrícola* 27:83-92.
- Pandorf H, Silva IJO, Piedade SMS (2008) Conforto térmico para matrizes suínas em fase de gestação, alojadas em baias individuais e coletivas. *Revista Brasileira de Engenharia Agrícola e Ambiental* 12:326-332.
- Rocha JS, Silva AS, Brito MA, Silva TPDE, Pereira AM (2012) Características termorreguladoras de diferentes linhagens de suínos na microrregião do Alto Médio Gurgueia. *Revista Verde* 7:140–143.
- Rossi LA, Velloso NM, De Lima MT, Sarubbi J, Vieira LHS (2012) Análise do desempenho reprodutivo e do uso de energia elétrica em instalações climatizadas de cachaços. *Revista Brasileira de Engenharia Agrícola e Ambiental* 16:1121-1127.
- Sampaio CAP, Cristani J, Dubiela JA, Boff CE, Oliveira AO (2004) Avaliação do ambiente térmico em instalações para crescimento e terminação de suínos utilizando os índices de conforto térmico nas condições tropicais. *Ciência Rural* 34:785-790.
- Sampaio CAP, Nääs IA, Nader A (2005) Gases e ruídos em edificações para suínos: Aplicação das normas NR-15 e ACGIR. *Engenharia Agrícola* 25:10-18.
- Sampaio CAP, Nääs IA, Salgado DD, Queirós MPG (2007) Avaliação do nível de ruído em instalações para suínos. *Revista Brasileira de Engenharia Agrícola e Ambiental* 11:436–440.
- Sarubbi J, Rossi LA, Moura DJ, Oliveira RA, Maia APA (2012) Nocturnal thermal comfort in facilities for growing swines. *Engenharia Agrícola* 32:1034-1040.
- Silva KO, Nääs IA, Tolon YB, Campos LSL, Salgado DD (2007) Medidas do ambiente acústico em creche de suínos. *Revista Brasileira de Engenharia Agrícola e Ambiental* 11:339-344.
- Silva-Miranda KO, Borges G, Menegale VLC, Silva IJO (2012) Efeito das condições ambientais no nível de ruído emitido por leitões. *Engenharia Agrícola*, 32:435-445.
- Souza AD, Pavão HG, Lastoria G, Gabas SG, Cavazzana GH, Paranhos Filho AC (2010) Um estudo de conforto e desconforto térmico para o mato grosso do sul. *REA – Revista de estudos ambientais* 12:15-25.
- Tinoco IFF, Souza CM, Oliveira PAV, Paulo RM, Campos JA, Carvalho CCS, Cordeiro MB (2007) Avaliação do índice de temperatura do globo negro e umidade e desempenho de suínos nas fases de crescimento e terminação criados em sistemas em cama sobrepostas em condições de verão. *Revista Brasileira de Zootecnia* 38:1624-1629.
- Tolon YB, Nääs IA (2005) Avaliação de tipos de ventilação em maternidade de suínos. *Engenharia Agrícola*, 25:565-574.
- Tolon YB, Baracho MS, Nääs IA, Rojas M, Moura DJ (2010) Ambiência térmica, aérea e acústica para reprodutores suínos. *Engenharia Agrícola* 30:1-13.
- Turco SHN, Ferreira AS, Oliveira RFM, Aguiar MA, Cecon PR, Araújo GGL (1998) Desempenho de porcas e leitões em maternidade com diferentes sistemas de acondicionamento térmico no inverno. *Revista Brasileira de Zootecnia* 27:988-993.
- Veríssimo CJ, Titto CG, Katiki LM, Bueno MS, Cunha EA, Mourão GB, Otsuk IP, Pereira AMF, Nogueira Filho JCM, Titto EAL (2009) Tolerância ao calor em ovelhas Santa Inês de pelagem clara e escura. *Revista Brasileira de Saúde e Produção Animal*, 10:159-167.
- Vieira RFN, Silva KO, Mello SP, Martins JR (2010) Índices de conforto na avaliação do bem estar animal de matrizes suínas em diferentes sistemas de criação. *Nucleus Animalium*, 2:1-8.