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Air quality, sound pressure level, and thermal environment of two swine nursery styles[1]

Qualidade do ar, nível de pressão sonora e ambiente térmico em creches de suínos

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ABSTRACT - Because of the importance of the ambiance in swine facilities, this study aimed to evaluate the air quality, the sound pressure level, and the thermal environment of two distinct swine nursery styles. A completely randomized block design with a split-plot arrangement was used, in which the main plots were composed of the nurseries and the external environment; the subplots were the hours; and the replications were the collection days. Air temperature data (°C), relative humidity (%), and black globe humidity index (BGHI) data were collected throughout the day at 10-min intervals, with means compared by Tukey's test at 0.05 probability level. Instantaneous concentrations of ammonia (ppm), carbon dioxide (ppm), and sound pressure levels (dB(C)) were measured three times daily and analyzed on boxplot graphs. The results showed no difference between the two nurseries with respect to thermal, air, and acoustic environment. The nurseries can be considered uncomfortable for the animals with respect to thermal conditions. Concentrations of gases and sound pressure levels did not exceed the limits established by current regulations. In both nurseries only at 09h00 it was possible to detect sound pressure levels that characterize the condition of comfort thermal of the environment, at the other times, alert and stress conditions were observed.

Key words: Rural buildings. Piglets. Gases. Noise. Thermal ambience.

RESUMO - Diante da importância da ambiência nas instalações para suínos, objetivou-se com o presente trabalho avaliar a qualidade do ar, nível de pressão sonora e o ambiente térmico em duas instalações de creches de suínos de tipologias diferentes. O delineamento experimental foi o de blocos casualizados com parcelas subdivididas. As médias de temperatura do ar (°C), umidade relativa do ar (%) e o índice de temperatura do globo negro e umidade (ITGU) foram comparadas pelo teste Tukey em nível de 0,05 de probabilidade. As concentrações instantâneas de amônia (ppm), dióxido de carbono (ppm) e níveis de pressão sonora (dB(C)) foram medidas três vezes ao dia e analisados por meio de gráficos *boxplot*. Os resultados mostram que não houve diferença entre as duas creches com relação ao ambiente térmico, aéreo e acústico. As creches podem ser consideradas desconfortáveis, para os animais no que diz respeito às condições térmicas. As concentrações dos gases e nível de pressão sonora não ultrapassaram os limites estabelecidos pela norma vigente. Em ambas as creches, apenas às 9 horas, foi possível detectar níveis de pressão sonora que caracterizam a condição de conforto térmico do ambiente, nos demais horários a condição é de alerta e estresse.

Palavras-chave: Construções rurais. Leitões. Gases. Ruídos. Ambiência térmica.

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INTRODUCTION

In animal facilities, the characteristics of the internal environment are analyzed by the thermodynamics, acoustics, and quality of the air (RODRIGUES *et al*., 2011). The thermal environment has a crucial importance for the success of the pig farming activity (VIEIRA *et al*., 2010). However, improper climatic conditions of facilities and the lack of knowledge of ambience principles are the main causes of losses reported in all production stages (CARVALHO *et al*., 2013).

Many studies have been developed to characterize the ideal thermal conditions in each pig production stage aiming to provide better comfort conditions and consequently higher production. In the production system, the nursery stage is fundamental, because the developmental ability of the subsequent stages can be practically predetermined in that period.

According to Sousa Júnior *et al*. (2011), in the nursery phase, the comfort temperature is between 24 ºC and 26 ºC and relative humidity is between 60 and 80%. For Ferreira (2011), in the nursery phase, the comfort temperature is from 22 ºC to 26 ºC, with 70% relative humidity.

Indices have been proposed aiming to quantify the combined influence of the main variables affecting thermal comfort, presenting, through mathematical calculations, the comfort of a given animal in relation to the environment where it is inserted. According to Abreu *et al*. (2011), the black globe humidity index (BGHI) best characterizes the animal thermal environment. Nunes *et al*. (2008) consider a BGHI of 74.5 as a thermoneutral environment for the nursery phase (6 to 15 kg).

In pig-farming facilities, the animal lives in an environment with high levels of gases, noise, and dust that often exceed the limits required for the maintenance of welfare and animal health (PANDORFI; ALMEIDA; GUISELINI, 2012). Among the gases present in swine facilities are ammonia (NH_3) and carbon dioxide (CO_2).

Ammonia is produced during the biological degradation of wastes, and its volatilization is influenced by high temperatures, air velocity, and pH (FURTADO *et al*., 2012).

The concentration of CO_2 in facilities is affected by the building type and curtains management (BANHAZI *et al*., 2011). Chang *et al*. (2001) observed that, in open facilities, the presence of gas is minimized by the building features, resulting in lower concentrations when compared with closed facilities.

Vocal emissions may serve as an indicator of the quality of life of animals and as an instantaneous, non-invasive assessment of welfare (DÜPJAN *et al*., 2008). In this regard, many studies have been undertaken to evaluate the sound pressure level and the thermal comfort in facilities for the pig production cycle (BORGES *et al*., 2010; CASTRO *et al*., 2013; MIRANDA *et al*., 2012; SAMPAIO *et al*., 2007).

Given the foregoing, the present study aimed to evaluate environmental comfort in two swine nursery facilities of different building types by analyzing the thermal, air, and acoustic conditions.

MATERIAL AND METHODS

This study was carried out in two swine nursing facilities of *Niterói* Farm, located in Lavras-MG, Brazil (21º14’ S latitude and 45º00’ W longitude; 918 m altitude) in the period from August 22 to September 2014. According to the Köppen classification, the climate of the region is a subtropical rainy temperate (mesothermal) Cwa type with dry winters and rainy summers, with an average annual temperature of 20.4 ºC (DANTAS; CARVALHO; FERREIRA, 2007).

The farm had a full-cycle pig production system, i.e., the animals were confined from birth to slaughter. Nursing facilities were intended for the production of commercial hybrid pigs for 35 days. Animals entered the nurseries at 21 days of age and left them at 56 days of age.

The diet was prepared on the farm according to the nutritional requirements and specific intake of the animals in this production stage. The diet was provided in a feeder with automatic distribution, and water was supplied by automatic nipple drinkers with no restrictions to consumption.

Nurseries oriented in the east-west direction and had the same external structure, with 2.40 m-high metal columns, gable roofing with 30% slope, fibrocement tiles with 6 mm thickness supported by a metal structure without a louver and 0.45 m eaves. The sides were fully covered with yellow canvases with adjustable height.

Nurseries had different internal structures. Nursery 1 measured 31.02 × 10.38 m (length × width) and had a 0.90 m-long central corridor with 1.94 × 4.00 m-sided stalls. Suspended 0.50 m above the ground, stalls were made of masonry, with 0.68 m in height, equipped with a 0.32 m-high protective metal grid above the masonry wall and around the stall. The floor was a metal mesh type, with a 1.00 × 1.50 m central concrete part where the automatic feeder was located. The nipple drinker was located on the left side of the stall. The heating system was provided by 250 W infrared bulbs fixed 0.40 m from the concentrate, at a height of 0.55 m. Nursery 1 was closed at every three stalls up to the roof by translucent corrugated sheets (Figure 1) and its housing capacity was 720 animals, with 24 piglets per stall (two litters).

Nursery 2 measured 23.61 × 10.10 m (length × width) and had a 0.90 m-long central corridor with twelve 1.94 × 4.00 m-sided stalls. Stalls were closed with wood laths with 0.80 m in height and polyethylene mesh floor at the level of the central corridor. Below the floor level was a 1.50 m deep ditch for waste. The feeder, the drinker, and the heating system were positioned as in nursery 1. At every three stalls, Nursery 2 was closed by concrete slabs at the same height as the stall (Figure 1), and its housing capacity was 576 animals, with 24 piglets per stall (two litters).

In the nurseries, there was a divider at every set of three stalls, forming a microenvironment between them. To better represent it, thermal comfort, air quality, and sound pressure level data were collected from the central stall of the set. Air temperature, air relative humidity, and black globe temperature were collected automatically using dataloggers (Hobo, U12-013) with an accuracy of ± 0.5 °C, at 10-min intervals, for 24 h, for the 35 days during which the piglets remained in the nurseries. Sensors were coupled to the dataloggers and placed in the globe for its temperature collection. To prevent interferences from the heat emitted by the heating system in the measurements, the datalogger was installed at a height of 0.80 and 0.70 m apart from the heating system. For the same reason, the black globe was installed at a height of 0.55 m and placed 0.50 m from the heating system. In the nurseries' external environment, the datalogger and the globe were also installed at the same height as those inside the stalls.

The black globe humidity index (BGHI) was calculated based on the thermal environment data using Equation 1 below, developed by Buffington *et al*. (1981):

$$BGHI = BGt + 0.36\,DPt - 41.5 \tag{1}$$

where: BGt = black globe temperature (°C); and DPt = dew point temperature (°C).

Using the thermal environment dataset obtained experimentally, the BGHI was determined for the temperatures presented by Ferreira (2011) aiming to characterize the thermal conditions of comfort, alert, and stress by this index.

The instantaneous concentration of NH_3 was obtained using a Testo® sensor (model 316-4) with "electrochemical principle", resolution of 1 ppm, accuracy of ± 1 ppm, and a measuring range of 0 to 100 ppm. For CO_2 data collection, a Testo® meter (model 535) with "infrared principle", resolution of 1 ppm, accuracy of ± 50 ppm, and a measuring range of 0 to 10,000 ppm, was used.

The sound pressure level (noise) was determined at the height of the animals using an Instrutherm® (model DEC-460) sound pressure meter with resolution of 0.1 dB and precision of ± 1.5 dB, at "C" weighing, as described by Borges *et al*. (2010).

Gases and sound pressure levels were collected at 09h00, 12h00, and 15h00, for 15 non-consecutive days, during the experimental period of 35 days.

A randomized-block design with split-plots was adopted for the variables referring to thermal comfort (BGHI, air temperature, and air relative humidity), in which plots consisted of the treatments nursery 1, nursery 2, and external environment; subplots were the times (1 to

Figure 1 - Internal structure of nursery 1 (left) and nursery 2 (right)

24 h); and the replicates were the collection days (35 days). Data were subjected to analysis of variance, employing the F test, and means were compared by Tukey's test at 5% significance using Sisvar® software for the statistical analyses (FERREIRA, 2008).

For the statistical analysis of the continuous quantitative variables ammonia, carbon dioxide, and sound pressure level, computer program Minitab® 17 (MINITAB, 2013) was used, consisting of boxplot graphs with median, first and third quartiles, and inter-quartiles.

RESULTS AND DISCUSSION

The analyses of variance show that factors and interactions were significant for all studied variables (Table 1). The present study will focus on analyzing the breakdown of the interaction between treatment and time.

The means for the variables in the nighttime period (18h00 to 06h00) differed statistically from those of the daytime period (07h00 to 17h00), for all treatments. However, at the times that composed the periods (nighttime and daytime), means were statistically equal.

Ferreira (2011) considers the relative air humidity of 70% as ideal for pigs in the nursery phase and proposes temperature ranges to characterize the thermal conditions of comfort, alert, and stress. BGHI values were obtained for these thermal conditions using the dataset of the experiment, based on temperatures proposed by the afore-mentioned author.

During the evaluated period, mean values for air temperature in nursery 1 and nursery 2 were within the comfort zone only between 08h00 and 10h00 and 18h00 and 20h00 (Tables 2 and 3); at the other times, the temperature was either below the comfort range (nighttime and early morning), indicating cold stress, or in alert condition (early afternoon to dusk). The air relative humidity in both nurseries was below the range considered ideal between 10h00 and 19h00. Mean values for temperature and air relative humidity in the external environment followed the same trend as those inside the facilities, but statistically different. According to Campos *et al*. (2009), closed pig nurseries have a lower thermal amplitude and consequently greater comfort condition; this was not observed in nursery 1, which is architecturally more closed than nursery 2.

Mean values for BGHI in nurseries 1 and 2 were in the comfort condition only from 09h00 to 11h00 and from 16h00 to 18h00; thus, during most part of the evaluated period, the nurseries were below the comfort zone or in alert condition. In the external environment, a small period of thermal stress conditions was observed, but within the facilities the conditions indicated thermal alert. Nunes *et al*. (2008) considered the value of 74.5 as comfort. Campos *et al*. (2008), in turn, consider a BGHI range of 68.9 to 78.5 for the same situation. Manno *et al*. (2005) report a BGHI value of 84.9 as a thermal stress condition.

The descriptive analysis of the air quality data in relation to the nurseries and times of data collection show that there was no statistical difference for the medians of the concentration of gases according to the confidence interval of 95% (Table 4).

The coefficients of variation obtained for NH_3 referring to the nurseries and to the times were high, which indicates an elevated dispersion of the values relative to the means. Nevertheless, the opposite was observed when CO_2 was analyzed. The median of the NH_3 concentration in nursery 1 was lower than that of nursery 2, just as the medians of the NH_3 concentration between collection times in nurseries 1 and 2 (Figure 2).

The highest ammonia concentration in nursery 1 was 6 ppm, at 12h00 and 15h00. In nursery two, the highest concentration was 8 ppm, at 09h00 and 12h00. Absence of NH_3 was observed in nursery 1 at 09h00 and 12h00 and in nursery 2 at 12h00 and 15h00. Concentrations of NH_3 were below 20 ppm, the maximum limit recommended by the International Committee of Agricultural Engineering

Table 1 - Analyses of variance for air temperature, air relative humidity, and BGHI of Nursery 1, Nursery 2, and External Environment

Source of variation	DF	Air temperature (°C)		Air relative humidity (%)		BGHI	
		MS	F	MS	F	MS	F
Treatment	2	643.89	119.55*	1634.97	332.18*	202.58	12.21*
Day	32	245.97	45.67*	3653.43	71.91*	473.02	28.50*
Treatment × Day	64	5.38		50.81		16.6	
Hour	23	3256.69	757.75*	27900.39	833.72*	5144	747.03*
Treatment × Hour	46	54.23	12.62*	671.72	20.07*	519.43	75.43*

DF - degree of freedom; MS - mean square; F - calculated F value; * - significant at 5% by the F test

Table 2 - Mean values for air temperature, air relative humidity, and BGHI of Nursery 1, Nursery 1, and External Environment

Hour	Air temperature (°C)			Air relative humidity (%)			BGHI		
	Nursery 1	Nursery 2	Ext. envir.	Nursery 1	Nursery 2	Ext. envir.	Nursery 1	Nursery 2	Ext. envir.
1	18.04 b	17.53 b	14.35 a	72.94 a	74.32 a	83.66 b	65 b	64 b	59 a
2	17.63 b	17.15 b	13.90 a	73.88 a	75.17 a	85.03 b	64 b	64 b	58 a
3	17.33 b	16.86 b	13.52 a	74.42 a	75.67 a	85.84 b	64 b	63 b	58 a
4	16.94 b	16.42 b	12.95 a	75.29 a	76.84 a	87.74 b	64 b	63 b	57 a
5	16.61 b	16.15 b	12.49 a	75.74 a	77.38 a	88.81 b	63 b	63 b	57 a
6	16.69 b	16.42 b	13.51 a	76.17 a	77.37 a	87.49 b	64 b	64 b	59 a
7	18.60 a	18.95 a	18.63 a	75.05 a	73.81 a	74.07 a	66 a	67 a	71 b
8	21.60 a	21.79 a	22.56 a	68.77 b	67.15 b	61.79 a	70 a	70 a	75 b
9	24.32 a	24.07 a	25.18 a	59.85 b	58.63 b	52.16 a	73 a	72 a	81 b
10	26.65 ab	26.23 a	27.55 b	52.22 b	50.77 b	44.38 a	75 a	74 a	85 b
11	28.47 ab	28.06 a	29.50 b	46.68 b	44.92 b	39.38 a	76 a	76 a	88 b
12	29.60 a	29.57 a	30.01 a	43.23 b	40.64 b	36.34 a	77 a	78 a	88 b
13	30.18 a	30.41 a	30.88 a	40.41 b	37.44 ab	33.94 a	77 a	78 a	86 b
14	30.25 a	30.62 a	31.91 b	39.15 b	36.06 b	31.40 a	77 a	78 a	82 b
15	29.90 a	30.24 a	30.85 a	38.90 b	35.56 ab	31.94 a	77 a	78 a	78 b
16	28.98 a	29.40 a	30.87 b	40.62 b	37.08 b	32.43 a	76 a	77 a	78 a
17	27.63 a	27.47 a	26.41 a	44.90 a	42.61 a	41.34 a	75 b	74 b	70 a
18	25.04 b	24.26 b	21.75 a	52.85 a	52.49 a	55.86 a	72 b	71 b	65 a
19	23.01 b	22.1 b	19.25 a	58.53 a	59.19 a	64.24 b	70 b	69 b	63 a
20	21.57 b	20.68 b	17.67 a	62.65 a	63.86 a	70.40 b	69 b	68 b	62 a
21	20.58 b	19.72 b	16.60 a	65.84 a	67.35 a	74.69 b	68 b	67 b	61 a
22	19.84 b	19.05 b	15.99 a	68.13 a	69.70 a	77.50 b	67 b	66 b	60 a
23	19.23 b	18.53 b	15.40 a	69.62 a	71.35 a	79.64 b	66 b	65 b	60 a
24	18.51 b	17.95 b	14.79 a	71.61 a	73.03 a	82.07 b	65 b	65 b	59 a

Means followed by the same letter in the column, for each variable analyzed, do not differ at 5% by Tukey's test

Table 3 - BGHI values obtained from the thermal conditions considered ideal for animals in the nursery

Thermal condition	Temperature (°C)	BGHI
Comfort	22 to 26 °C	71 to 76
Alert	27 to 30 °C	77 to 82
Stress	> 30 °C	> 82

For Sousa Júnior *et al*. (2011), the temperature range for the comfort condition is more strict — from 24 to 26 ºC — and wider for the air relative humidity, which ranges from 60% to 80%

Table 4 - Descriptive analysis of NH_3 and CO_2 gases in relation to nurseries

Treatment	Variable	Mean	1st quartile	Median	3st quartile	IQR	Standard deviation	Coef. of variation
Nursery 1	NH_3	1.93	1.00	1.00	2.50	1.50	1.57	81.34
Nursery 2		2.42	1.00	2.00	3.00	2.00	1.84	75.97
Nursery 1	CO_2	645.70	556.50	644.00	700.00	143.50	110.80	17.15
Nursery 2		588.70	523.50	602.00	675.00	151.50	107.00	18.18

Figure 2 - NH_3 concentration in nurseries 1 and 2 and at collection times 09h00, 12h00, and 15h00 in both nurseries

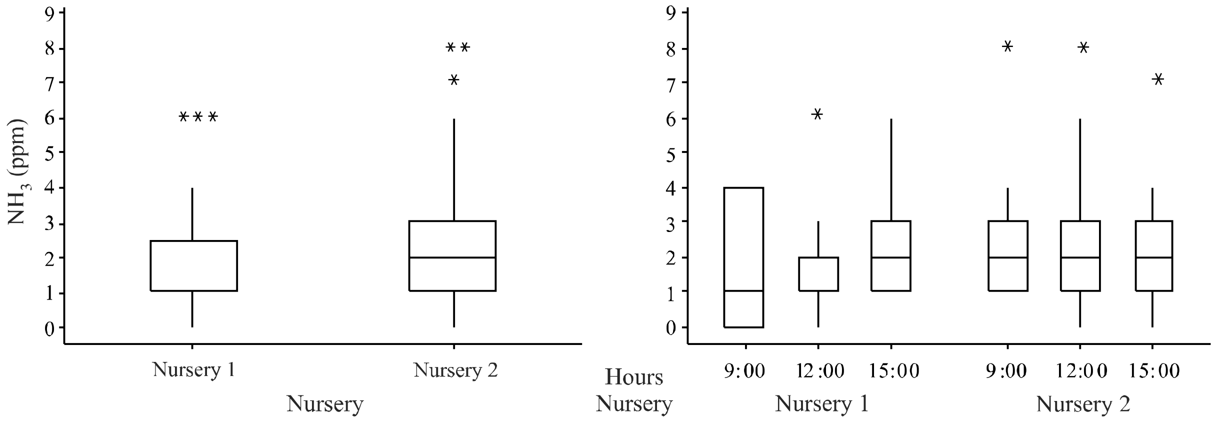


Table 5 - Descriptive analysis of NH_3 and CO_2 gases in relation to collection times

Treatment	Variable	Time	Mean	1st quartile	Median	3st quartile	IQR	Standard deviation	Coef. of variation
Nursery 1	NH_3	09h00	1.73	0.00	1.00	4.00	4.00	1.58	91.13
		12h00	1.67	1.00	1.00	2.00	1.00	1.40	83.84
		15h00	2.40	1.00	2.00	3.00	2.00	1.72	71.82
	CO_2	09h00	642.10	562.00	658.00	695.00	133.00	84.30	13.14
		12h00	626.80	542.00	617.00	689.00	147.00	123.20	19.66
		15h00	668.10	595.00	630.00	746.00	151.00	123.80	18.53
Nursery 2	NH_3	09h00	2.53	1.00	2.00	3.00	2.00	1.81	71.34
		12h00	2.53	1.00	2.00	3.00	2.00	2.10	82.89
		15h00	2.20	1.00	2.00	3.00	2.00	1.70	77.22
	CO_2	09h00	617.60	536.00	636.00	694.00	158.00	95.70	15.50
		12h00	577.70	453.00	570.00	683.00	230.00	124.60	21.56
		15h00	570.90	480.00	565.00	636.00	156.00	99.90	17.49

(*Commission Internationale du Génie Rural*, CIGR) (1994). Furtado *et al*. (2012) obtained average NH_3 concentration values of 5.2 ppm in pig nurseries.

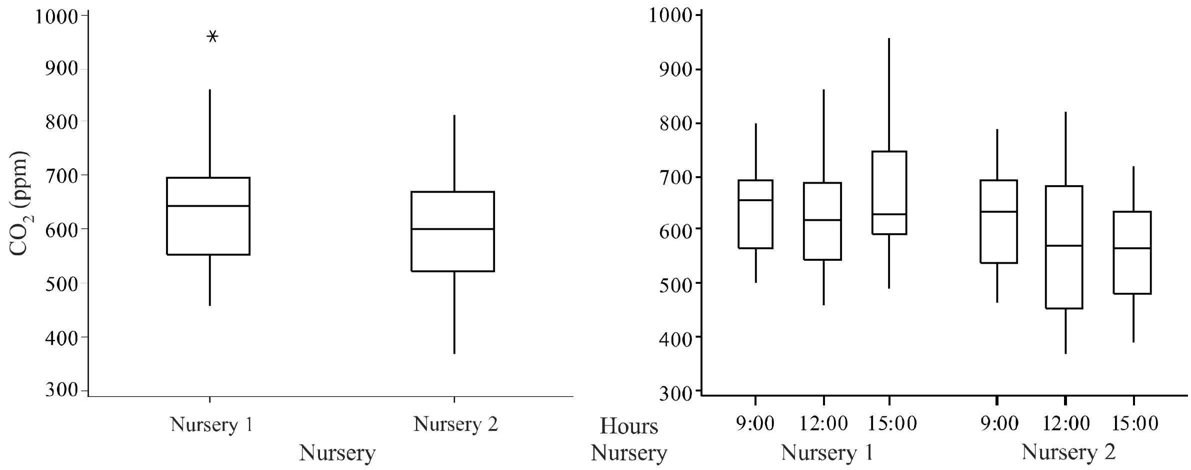
According to Chang *et al*. (2001), the building features open and closed interfere with the concentration of pollutants in the facilities. Sampaio, Nääs and Salgado (2006) evaluated the concentration of gases in two nursing types, one closed by masonry walls at every two stalls and with cemented floor (G1) and another with masonry walls at every 14 stalls and with 2/3 of the floor cemented and 1/3 covered with perforated plastic sheets (G2). These authors found that, in the winter, that NH_3 levels were higher in G1 (more closed nursery) than in G2, with the lowest mean value of 4.1 ppm obtained in the morning, and the lowest, 26.0 ppm, in the afternoon period.

The median of the CO_2 concentration in nursery 1 was higher than that found in nursery 2 (Figure 3). The same was observed when the concentrations of CO_2 between collection times in nurseries 1 and 2 were analyzed.

The highest concentration of CO_2 in nursery 1 was 960 ppm, occurring at 15h00; the lowest was 458 ppm, at 12h00. In nursery 2, the highest concentration of CO_2 was 818 ppm, while the lowest was 368 ppm, both at 12h00.

Regarding the animals, the concentrations of CO_2 are below the 3,000 ppm recommended by Nader *et al*. (2002). Banhazi *et al*. (2011) found CO_2 concentrations between 750 and 1050 ppm in pig facilities. Silveira *et al*. (2009) observed maximum CO_2 values of 1500 ppm in pig nurseries.

Figure 3 - CO_2 concentration in nurseries 1 and 2 and at the collection times 09h00, 12h00, and 15h00 in both nurseries



In two pig nurseries with different sizes, Campos *et al*. (2009) found, at 09h00, 12h00, and 15h00, average CO_2 levels of 1204 and 1013 ppm, 997 and 876 ppm, and 1006 and 956 ppm, at an average air temperature of 23, 27, and 29 ºC, respectively.

Nursery 1, closed (masonry stalls), showed a greater concentration of gases than nursery 2, open (stalls with wood lath dividers), agreeing with the literature. However, the CO_2 and NH_3 concentrations found in the present study were lower due to the building type of the facilities and the curtain management, since they interfere with the air movement and consequently with the concentrations of gases inside the sheds.

The descriptive analysis of the sound pressure level (SPL) at the height of the animals in relation to the nurseries (Table 6) and collection times (Table 7) show that, statistically, there was no difference for the medians of the sound pressure level according to the confidence interval of 95%. The coefficient of variation was low, suggesting a slight dispersion of values in relation to the mean.

The maximum limit for sound pressure level in swine facilities, according to the Department for Environment, Food and Rural Affairs (DEFRA) (2003), is 85 dB. Above this value, the animal may be unable to develop its natural behavior (TOLON *et al*., 2010).

Table 6 - Descriptive analysis of the sound pressure level in relation to nurseries

Treatment	Variable	Mean	1st Quartile	Median	3rd Quartile	IQR	Standard deviation	Coef. Of variation
Nursery 1	SPL	73.31	71.85	73.30	74.60	2.75	3.38	4.61
Nursery 2		73.27	70.60	73.60	74.90	4.30	3.46	4.72

Table 7 - Descriptive analysis of the sound pressure level in relation to collection times

Treatment	Variable	Time	Mean	1st Quartile	Median	3rd Quartile	IQR	Standard deviation	Coef. Of variation
Nursery 1	SPL	09:00	74.02	72.40	73.80	75.30	2.90	2.22	3.00
		12:00	72.58	69.80	72.80	73.80	4.00	4.60	6.34
		15:00	73.33	72.20	73.30	74.70	2.50	2.94	4.02
Nursery 2		09:00	74.39	71.50	74.80	76.00	4.50	3.10	4.17
		12:00	73.06	69.60	72.40	74.60	5.00	4.56	6.25
		15:00	72.37	69.80	72.40	74.30	4.50	2.21	3.05

The sound pressure level in nursery 1 was mostly between 69.7 and 77.8 dB(C) and in nursery 2 between 79.7 and 67.3 dB(C) (Figure 4). Some values above and below these ranges were found, but in non-expressive amounts. In nurseries 1 and 2, at 12h00, the sound pressure level underwent a greater variation than at the other times, ranging from 9.7 to 11.2 dB(C), respectively.

Borges *et al*. (2010) evaluated the sound pressure level in a nursing facility and found values between 56.28 and 56.82 dB(C). Silva *et al*. (2007) found 72 to 76 dB(A) for the same productive phase. Therefore, the values observed in the present study are close to those found in the literature, using A or C weighing, and within the maximum limit for swine recommended by DEFRA (2003).

Miranda *et al*. (2012) related the sound pressure level to the thermal conditions of piglet nursing facilities and concluded that, for the comfort condition (20 to 23 °C), the noise levels would be in the range of 70 to 75 dB(C); alert condition (23 to 30 ºC), from 60 to 70 dB (C); and thermal stress condition (over 30 ºC), in the range of 55 to 60 dB(C).

Figure 4 - Sound pressure level in nurseries 1 and 2 and at collection times

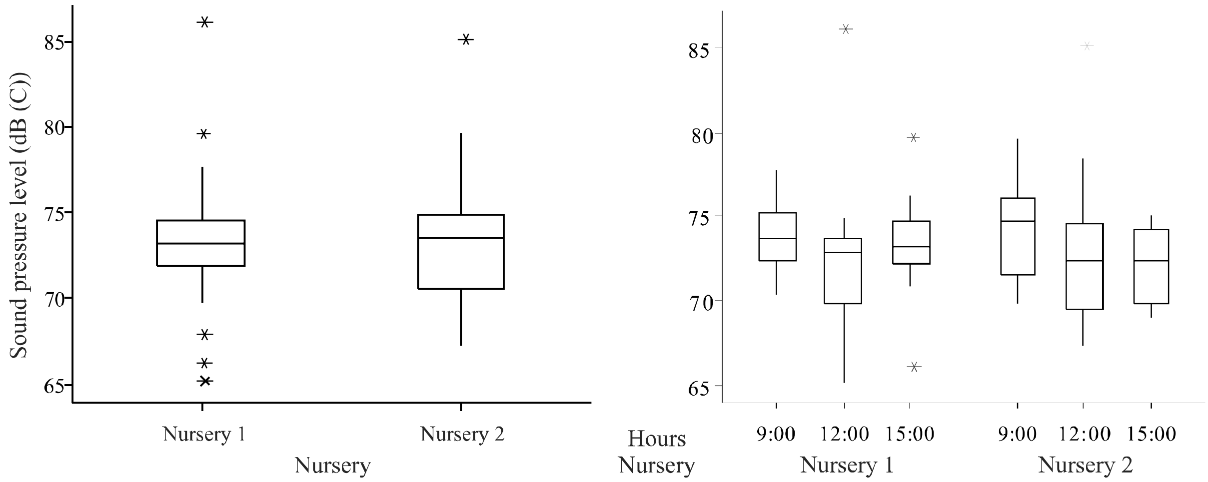
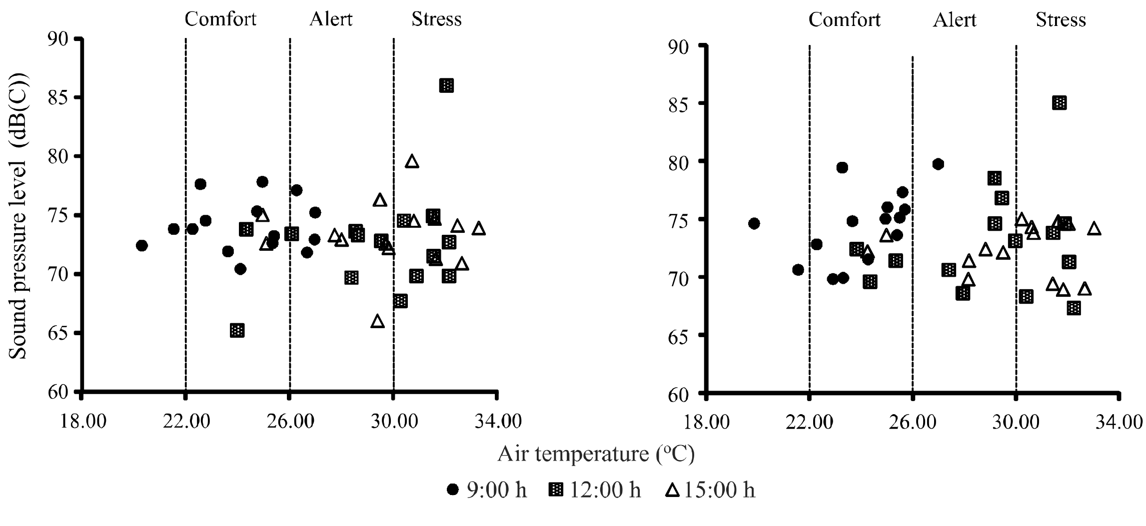


Figure 5 - Relationship between sound pressure levels and the temperature ranges that characterize the thermal conditions of comfort, alert, and stress



Analyzing the relationship between sound pressure levels and temperature ranges that characterize the thermal conditions of comfort, alert, and stress (Figure 5), we can observe that the sound pressure levels are concentrated in a short interval of 78 to 67 dB(C) in both nurseries.

At 09h00, the sound pressure levels in nurseries 1 and 2 were concentrated in the thermal comfort zone, varying from 70 to 78 dB(C), which are close values to those reported by Miranda *et al*. (2012). At the other times, the sound pressure levels were dispersed between the thermal alert and stress condition ranges.

CONCLUSIONS

1. There was no difference between the two nursery types as regards thermal conditions, air quality, and sound pressure level, but there was a difference between these variables throughout the day;
2. Nurseries can be considered uncomfortable for animals in respect to thermal conditions. In the nighttime period, nurseries tend towards cold stress, while during daytime the alert condition predominates, tending to heat stress;
3. Concentrations of carbon dioxide and ammonia gases in the facilities are below the limit established by current norms. There was no difference between the nurseries for concentrations of gases;
4. The sound pressure levels in the facilities are below the limit established by current norms. In both nurseries, only at 09h00 was it possible to detect sound pressure levels characterizing comfort conditions; at the other times, alert and stress conditions were present.

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