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Lighting and noise levels in compost dairy barns with natural and forced ventilation

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Abstract. The housing system, called compost barn, is attracting the interest of several farmers. It allows dairy cows to remain in free movement inside a shed without any containment partitions like those used in freestall barns. In Brazil the compost barns with open sides are very common, but recently some closed barns with climatic control systems have been implemented. The objective of this work was to evaluate and compare lighting and noise levels in an open compost barn with natural ventilation and in a closed compost barn with a climate control system. The latter one is based on tunnel ventilation: inlet of air trough evaporative cellulose panels and exit through fans placed on the opposite wall. Through analysis of the collected data it was observed that the sound pressure recorded inside both analysed buildings did not exceed the ranges of noise discomfort recommended for the rearing of animals. However, the sound pressure amplitude inside the barn with climate control system was greater than in the open barn. The light intensity was significantly lower in the closed barn when compared to the open barn (84.96 and 1,413.58 lx, respectively). The artificial lighting system distributed throughout the closed barn was not sufficient to maintain brightness within the recommended range for lactating cows. In addition, it was found that in the closed building with forced ventilation, the highest brightness values are located near the exhaust fans.

Key words: animal facility, dairy cows, compost-bedded pack barn, light intensity.

INTRODUCTION

Intensive milk production systems are commonly adopted by large producers around the world. In such systems care must be taken to ensure to the animals the appropriate environment throughout the year, that is one of the main challenges to win (Leão et al., 2015). Facilities used for dairy cows must be well designed to promote maximum animal comfort and mitigate the effects of climatic and physical factors that may interfere with the quality of production.

Compost bedded pack barns, generally known as compost barns, are alternative housing systems for dairy cows (Leso et al., 2013; Leso et al., 2019), attracting global interest. Compost barn is a housing system in which cows remain in free circulation within a covered shed (Eckelkamp et al., 2016; Leso et al., 2020). The system consists of confining the animals in facilities with a wide bedding area realized with organic matter substrates. The main purpose of bed materials is to absorb animal excreta and favour aerobic composting (Janni et al., 2007).

In naturally ventilated systems the facilities must be located in open areas to ensure natural ventilation to work well (Damasceno, 2012). The facility must be located with a slight elevation from the surrounding terrain to prevent the pack from getting wet during rainy periods, which would raise its humidity to undesirable levels (Janni et al., 2007).

When natural ventilation is not enough to improve the internal environment of the facility, it is necessary to use fans placed over both bedding area and feeding alley, aiming to reduce the heat load and improve air quality in the environment, besides to promote drying of the upper layer of the pack (Lobeck et al., 2012).

In Brazil, it is observed that many compost dairy barns are open on the sides, but recently some closed compost barns with climate control systems have been built. Currently, there is little information on the performance of completely closed compost dairy barns.

Fully enclosed facilities rely on mechanical ventilation and typically use evaporative cooling to reduce the temperature during the warmer months. In addition, some fully enclosed facilities for milk production install baffles, made of metal or canvas, to redirect airflow and to increase air speed to the space where the cows are located. The lower part of the baffles cannot interfere with the normal operation of machineries used to handle the bedding (Sheffield et al., 2007).

In this case, the way the system is built and the adaptation to hot weather conditions may allow the ideal temperature and air velocity to be maintained. The enclosed confinement system requires special attention in controlling environmental parameters that influence animal comfort and performance such as air temperature, relative humidity, air velocity, gas concentration, and dust (Damasceno et al., 2019). However, other factors, such as artificial lighting and fan noise, are important variables for the influence on livestock environment quality.

Several researchers investigated the effect of light day duration and light intensity on the main factors inflluencing the productive and reproductive performace in dairy cattle farms. Light is an essential component of farm animal environment. The lighting of facilities is necessary for a very important element of animal welfare that is the contact with other animals of the group (Phillips & Schofield, 1989; Dahl et al., 2000; Penev et al., 2014)

The physiological effect of light on dairy cows is well reported in the literature. Light intensity and the photoperiod influence the physiological response of dairy cows, impacting on growth, reproduction, and lactation. (Dahl et al., 2012).

Philips et al. (2000) tried to apply different levels of the light intensity (from 0 to 250 lx) in a cubicle passageway where cows walked to receive a food reward. They found that the optimum illumination for dairy cow locomotion could be considered between 39 and 119 lx.

Dahl et al. (2000) stated that to stimulate milk production the lighting system has to provide values of 150 lx of illuminance throughout the barn and 16–18 hours of continuous light.

The recommended illuminance levels for dairy livestock facilities, summarized by ASABE 2006 on several date collected in literature (MWPS, 1992; NFEC, 1993; Leech & Person, 1993), are the following: parlour, pit and near udder, 500 lx; parlour, stalls and return lanes, 200 lx; parlour, holding area, 100 lx; milking room, general, 200 lx; milking room, washing, 750–1,000 lx; stall barn, manger alley, 100 lx; stall barn, milking alley, 200 lx; drive-through, feed alley, 200 lx.

Lobeck et al. (2012) compared low profile cross-ventilated freestall and compost bedded pack barns for dairy cows. The authors observed that in the fully closed and air-conditioned freestall system the light intensity inside the facility was significantly lower than in compost barns and presented values close to the minimum for the light intensity recommended for cows during the lactation period.

The sensitivity of cattle to sound, and the levels to which they are exposed, has been reviewed by many authors. Thresholds for discomfort of cattle are indicated at 90–100 dB, with physical damage to the ear occurring at 110 dB (Phillips, 2009). Several studies show that sudden and unexpected sounds seem to have an impact on animal behaviour more than continuous high noise (Grandin, 1998; Arnold et al., 2007; Brouček & Slovak, 2014).

Oliveira et al. (2019), evaluating compost dairy barns with different ventilation systems, observed that the highest noise levels were observed close to fans or in the line of action of fans, as well as at the entrance to the feeding alley. The high noise levels were caused both by the presence of mechanical ventilation and by the presence of animals.

The objective of this work was to evaluate and compare the lighting and noise levels in a naturally ventilated compost dairy barn and in a compost barn with a climate control system by forced ventilation.

MATERIALS AND METHODS

General considerations

The survey was conducted in two compost dairy barns with different ventilation systems: climate controlled (CBC) and natural ventilation (CBN). The facilities are located on the same farm, in the city of Cajuri (Minas Gerais, Brazil), at 670 m altitude, coordinates 20° 46’ 41” S and 42° 48’ 57” W. The region's climate according to the Köppen classification is tropical in altitude, with rainy summers and cold and dry winters (Silva et al., 2004).

Evaluated treatments

a) The climate controlled compost barn (CBC) was built in May 2017. The dimensions of the CBN barn are 55.0 m × 26.4 m. It is oriented northwest-southeast. The feeding alley has a concrete floor and is 4 m wide. The feeding alley, which includes the waterers, is separated from the pack by a low concrete wall (1.2 m). The building has a concrete structure and is covered with metal sheets. The eave height is 5 m and eave overhang is 0.8 m. Throughout the barn, five baffles are installed, placed 3 m above the floor and spaced every 11 m. The colour of the baffles is light blue.

Five LED lamps (100W) are distributed along the bedding area and feeding alley.

During the trials the CBC barn was bedded with a mix of wood shavings and coffee shells. The depth of the bed was approximately 0.50 m. The pack (dimensions 55.0 m × 16.0 m) was aerated twice a day using a chisel with roller, coupled to a tractor, while the cows were milked. The pack was aerated to a depth of 0.20. This barn was not cleaned out during the year.

On the southeast side of the building, porous cellulose panels with dimensions 18.0×3.5 m are used for evaporative cooling. The panels are moistened by dripping to cool the air before entering the CBC. A temperature sensor located inside the CBC monitors environmental conditions and allows the system to remain on if the air temperature is above 21 °C and the relative humidity below 75%.

On the northwest side the facility has five exhaust fans (BigFan®, 3.5 m diameter, six propellers, air volume 150,000 m^3 h^{-1} volume and power of 2.0 HP). The five exhaust fans remain on continuously, 24 hours a day.

In the experimental period the CBC housed 88 lactating Holstein cows (600 kg) with a stock density of 10 m^2 cow^{-1}. The milk production per cow was 25 kg day^{-1}.

b) The natural ventilation compost barn (CBN) was built in July 2019. The dimensions of the CBN barn are 60.0 m × 24.0 m. The feeding alley is paved with concrete and is 4 m wide. The feeding alley, which includes the waterers, is separated from the pack by a low concrete wall (1.2 m). The structure of the building is in concrete. The roof is realized with metal sheets. The eave height is 6 m and eave overhang is 0.5 m.

A low concrete wall is present around the perimeter of the barn and wire cables are placed above the wall to prevent cows from falling or jumping onto feeding alley.

During the trials the CBN barn was bedded with a mix of wood shavings. The depth of the bed was approximately 0.30 m. The pack (dimensions 60.0 m × 14.0 m) was aerated twice a day using a chisel with roller, coupled to a tractor, while the cows were milked. The pack was aerated to a depth of 0.20. This barn was not cleaned out during the year. The barn has completely open sides to allow natural ventilation.

In the experimental period the CBN housed 63 lactating Holstein cows (600 kg) with a stock density of 13.3 m^2 cow^{-1}. The milk production per cow was 30 kg day^{-1}.

Data collection

The study was carried out during the month of August 2019, that is winter season in the southern hemisphere. The variables illuminance (lx) and noise (dB) were recorded inside the two compost barns in the morning shift.

The evaluated data were collected into a rectangular grid containing 54 equidistant points, placed over the bedding area and feeding alley. Therefore, the data were collected in the area of 60 m × 18 m (CBN) and 55 m ×20 m (CBC). The collection of illuminance and noise data in each barn occurred on the same day and time. The procedures for data collection for both facilities were similar. The variables were collected at a height of 1.5 m.

A portable digital lx meter (MINIPA, model MLM-1011, range from 0 to 100,000 lx with 4.0% accuracy) was used for the illuminance measurements. For noise level measurements, a digital sound pressure level meter (Instrutherm®, ITDEC 4,000 model, accurate to ± 1.5 dB, measuring filter: A) was used.

Statistical analysis

Descriptive statistics was used to determine the mean, standard error, median, coefficient of variation, kurtosis, minimum and maximum values for each of the variables analysed in both facilities.

The conditions of noise level and lighting verified inside each of the compost dairy barn studied were compared statistically by means of the Mann–Whitney test at the level of 5% of significance.

Subsequently, from the data collected, descriptive maps of lighting and noise were generated (data is interpolated into a grid for contour plots).

The SigmaPlot® 12.0 software was used as a tool statistics for all analyses performed.

RESULTS AND DISCUSSION

Illuminance (lx)

According to Table 1, the average light intensity results were 1,413.58 lx (286.67–4,523.33 lx) for the CBN system and 84.96 lx (3.0–492.67 lx) for the CBC system. According to the values mentioned above, it is observed that average light intensity (84.96 ± 18.39 lx) recorded in the CBC was below the ranges considered ideal for lactating cows. The variation coefficients showed high variability for the barns, being higher inside the CBC.

Table 1. Values of mean, standard error (SE), median, coefficient of variation (CV), minimum value (Min.), and maximum value (Max.) illuminance (lx), in climate controlled compost dairy barn (CBC) and natural ventilation compost dairy barn (CBN)

	Mean ± SE	Median	CV (%)	Min.	Max.
Illuminance (lx)					
CBN	1,413.58 ± 139.82	998.33	73	286.67	4,523.33
CBC	84.96 ± 18.39	24.66	159	3.0	492.67

Lighting is an important factor in the milk production sector and regulates the health and welfare of animals. Studies have shown that to observe an efficient production response in lactating cows, the recommended light intensity is about 160 lx (Buyserie et al., 2001; Dahl, 2001). With regard to lactation, increasing light exposure to 16 to 18 h d^{-1} (long-day photoperiod) with intensity of 200 lx enhances milk production on average (Dahl & Petitclerc, 2003).

According to NBR 5413 (1992), in places where general lighting is used continuously or areas with simple visual tasks (example in the region of the pack) the illuminance has to be from 100 to 200 lx. For the feeding alley, a minimum light level of 200 lx is recommended (House, 2015).

The lighting in the barns is also desired for inspecting animals and handling dairy cows. Cows move more easily through uniformly lit entrances and exits (Damasceno, 2012).

Fig. 1 shows the distribution of the light intensity based on data collected in the two facilities. A statistically significant difference was found between the data observed in the CBN and CBC barns.

The highest average values found in the CBN in comparison to those observed in the CBC are within the expected range, because the intensity of the CBN light depends mainly on the external conditions.

In a study by Lobeck et al. (2012) who evaluated and compared the light intensity in a closed installation with mechanical ventilation, low profile cross-ventilated freestall (CV), open compost barn (CB) and naturally ventilated freestall (NV), the results showed that light intensity was significantly lower in CV system than in CB and NV (111, 480 and 392 lx, respectively). The results were similar to those found in this study.

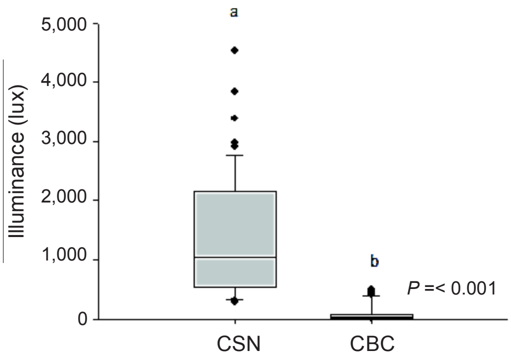

Figure 1. Distribution charts for illuminance data, in lux, during the winter period, in climate controlled compost barn (CBC) and natural ventilation compost barn (CBN). Averages followed by the same letters do not differ from each other at the 5% probability level by the Mann-Whitney test.

The CBC barn showed values of light intensity below that recommended for lactating dairy cows until the end of the study. It is observed that the closed barn had influence on the luminous intensity values, indicating that modifications need to be made in order to improve the lighting conditions inside. Lobeck et al. (2012) recommend that producers who build compost barns install additional lighting because the efficiency of the lamps decreases over time and due to the presence of dust.

For the CBN and CBC facilities, results on the lighting intensity showed that there was variation of this variable inside the facility, with greater amplitude for the CBN (Fig. 2, a, b).

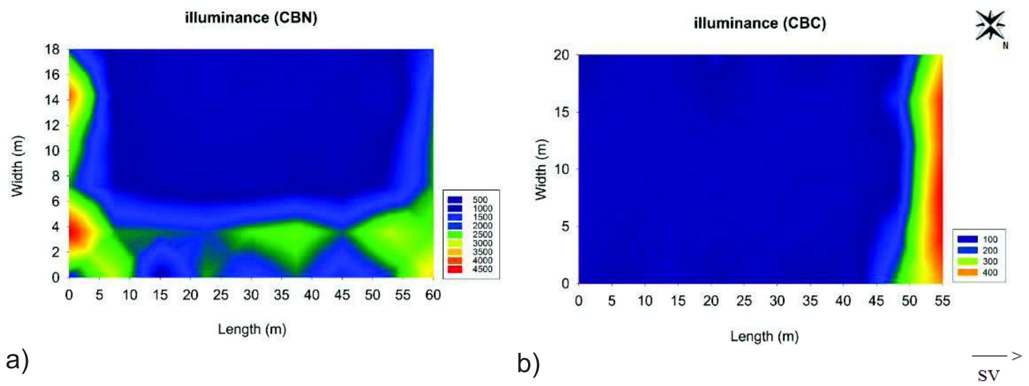

Figure 2. Maps of illuminance, in lx, during the winter period, in in climate controlled compost barn (CBN) and natural ventilation compost barn (CBC). SV – sense of ventilation.

It is observed that the CBN (Fig. 2, a) had a huge amplitude, and a pattern of higher light intensity concentration in the northwest, southwest and southeast faces of the house. It was observed that the presence of the overshot ridge, from the data collected in the morning, contributed to the greater passage of light in parts of the facility, which could be observed near the southwest face of the installation.

The lamps were not evenly arranged within the CBC barn (Fig. 2, b), so a variation in illuminance values was expected. In addition, in CBC the light intensity presented the highest values in the region near the hoods, which occurs due to its large diameter, allowing a greater passage of light.

Noise Levels

According to Table 2, the average noise levels present a mean value of 51.58 dBA (48.13–53.63 dBA) for the CBN system and of 54.45 (49.57–62.87 dBA) for the CBC system. It is observed that the maximum noise level values found in both facilities did not exceed the noise discomfort ranges, indicating a comfortable sound condition, resulting in tranquillity for the animals. Phillips (2010) classifies the range for hearing discomfort in cows between 90 and 100 dB, with physical damage occurring close to 110 dB.

Table 2. Values of mean, standard error (SE), median, coefficient of variation (CV), minimum value (Min.), and maximum value (Max.) noise (dBA), in climate controlled compost barn (CBC) and natural ventilation compost barn (CBN)

	Mean ± SE	Median	CV (%)	Min.	Max.
Noise (dBA)					
CBN	51.58 ± 0.16	51.61	2.3	48.13	53.63
CBC	54.45 ± 0.49	53.31	6.6	49.57	62.87

The variation coefficients showed low variability for the barns, being higher inside the CBC.

The distribution of the noise level data verified in the two facilities is presented in Fig. 3. A statistically significant difference was found between the data observed in the CBN and CBC.

CBN presented lower average values than CBC, with a more uniform distribution when compared to CBC. The results found in this study were similar to those presented by Damasceno et al. (2019). The lower values of sound pressure observed in CBN are mainly due to the vocalization of animals, the management operations and external sources.

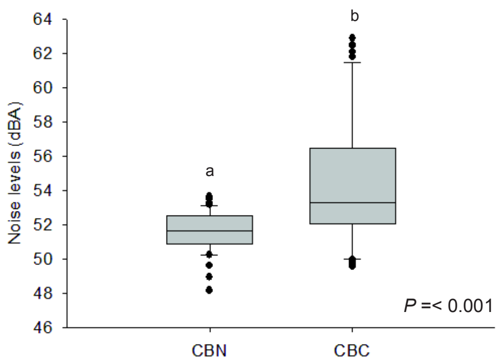

Figure 3. Distribution charts for noise level data, in dBA, during the winter period, in climate controlled compost barn (CBC) and natural ventilation compost barn (CBN). Averages followed by the same letters do not differ from each other at the 5% probability level by the Mann-Whitney test.

For the CBN and CBC facilities, the results on the noise levels showed that there was variation of this variable inside the installation, with greater amplitude for the CBC (Fig. 4, a, b).

The results found in this study are similar to those presented by Garcia (2017), in which closed freestall facilities with climate control and open facilities were compared for the confined dairy cattle. The authors observed that the closed facilities presented greater amplitude (26.26 dB) in the sound pressure levels in relation to the open installations (7.8 dB) in trials carried out during the autumn, in the morning period. In this study, the sound pressure recorded in the confinement sheds also did not exceed the ranges of noise discomfort.

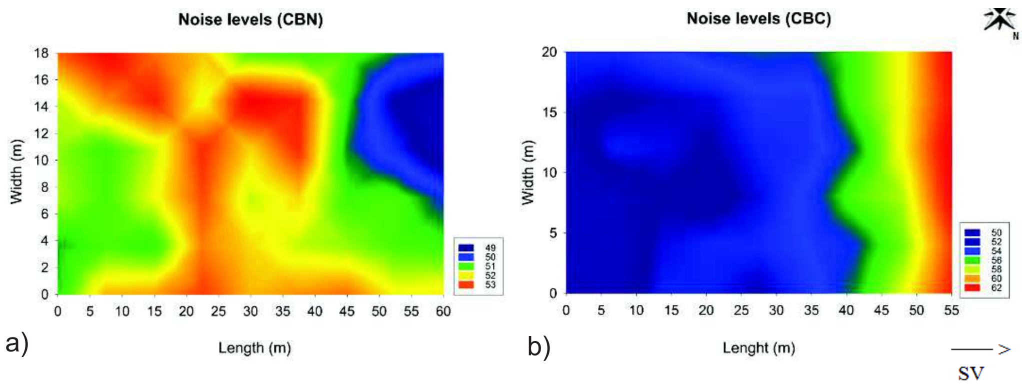

Figure 4. Maps of noise levels, in dBA, during the winter period, in climate controlled compost barn (CBC) and natural ventilation compost barn (CBN). SV – sense of ventilation.

The results showed (Fig, 4, b) the increase of noise in the region near the exhaust fans (62 dBA) in the CBC installation, being the highest values observed in the face where they were located, allowing to state that its occurrence is due to the characteristic noise caused by the rotation of the exhaust fans. On the opposite side of the CBC, close to the evaporative cooling plates, mean sound pressure values of 50 dB A were found.

The results are in agreement with other authors. Smith & Harner (2007) evaluated a cross-ventilated facility and found average noise levels below 65 dB, regardless of the number of fans in operation. In another study Damasceno et al. (2019), in CBC barn, found noise level values from 45 to 70 dB. The highest values were observed in the area immediately next to the face where the fans were located, due to their rotation.

CONCLUSIONS

The natural ventilation compost barn presented, as expected, more light intensity when compared to climate controlled compost barn. In the latter, the artificial lighting system distributed throughout the facility was not sufficient to maintain the light intensity within the range recommended for lactating cows.

The sound pressure recorded inside the compost barn did not exceed the ranges of noise discomfort recommended for the rearing of animals in both the two facilities analysed. The facilities with artificial climatic control systems had average noise values below 62 dBA.

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