

Comparative analysis of performance by cows confined in different typologies of compost barns

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Abstract. The compost barn system was designed to be a sustainable alternative housing system for dairy cows. In order to help producers in the region to choose the best type of facility from the point of view of the milk production of the animals, this study compared the productivity of cows confined in an open composting barn with natural ventilation and in a closed composting barn with negative pressure ventilation and evaporative cooling panels. The temperature and relative humidity of the air were monitored, as well as the milk production of the animals housed in the facilities, and THI (Temperature and Humidity Index) were calculated. During the trials, the maximum daily temperatures of the air reached values around 27 °C and the THI remained within the normal range of up to 70. The average productivity remained in the general pattern described in the literature from 23 to 44 kg of milk cow⁻¹ day⁻¹, with lower rates obtained in the closed house. As the variation of the index used to describe the internal environment was not significant, it can be inferred that climatic elements as temperature and air humidity, under the conditions analyzed were not the main factors influencing the productivity rates of dairy cattle. In conclusion, under the analysed conditions the use of a closed barn with negative pressure ventilation is hardly justified as a plant that favoured the productivity of the confined cows.

Key words: compost-bedded pack barn, dairy cows, cattle housing, thermal comfort.

INTRODUCTION

Brazil is an important world producer of milk, equivalent to approximately 35 billion litres in 2018. This activity represents one of the main sources of economic income for the Country (EMBRAPA, 2019).

As Brazil includes tropical and sub-tropical areas, the climatic conditions represent an important factor, which significantly affects milk productivity, also for the reason that the animals with higher yields come from countries with temperate climate. A form of intervention to overcome this type of problem is the adoption of facilities with climate control to alleviate the effect of heat stress on the animals and thus reduce productive losses.

Thus, to maintain high levels of production combined with good conditions of comfort and welfare of animals, studies to improve confinement situation have been intensified in recent years. For dairy production in Brazil, there is still predominance of grazing systems, but in some Brazilian States an increase in the number of producers opting for feedlot systems with greater control of environmental variables has been remarked (Pilatti, 2017).

Compost-bedded pack barns (CBP), generally known as compost dairy barns, are alternative housing systems for dairy cows (Leso et al, 2013; Leso et al., 2020). In these barns, the whole surface of the resting area is covered with a deep-bedded pack that is frequently stirred in order to incorporate fresh manure into the pack and to enhance the evaporation of water. The cows remain in free circulation within a covered shed without any containment partitions, like those present in freestall and tie-stall systems (Eckelkamp et al., 2016). The diffusion of this system is mainly due to its efficiency, since, in addition to provide greater comfort to animals, it also allows to obtain manure of good quality. Studies have indicated that CBP, compared with conventional systems such as freestall barns, have the potential to improve the welfare of dairy cows. CBP housing system may improve longevity of dairy cows, which is reported to be one of the most important motivations for building this kind of housing (Leso et al., 2019).

The construction and materials used for buildings can influence together with technological equipment and system of ventilation the microclimatic conditions inside the sheds (Kic, 2016). The compost barns can be made by applying simple construction techniques, also referred to green-house type building (Leso et al., 2017) and to the use of emerging principle of 'design for deconstruction' extensively (Leso et al., 2018).

The profitability of the composting granary has been studied in several studies. De Oliveira et al. (2019) compared the milk production systems of the composting barn and free stall. They have concluded that the requirements for choosing the most suitable installation should be based on the ease of handling, productive and reproductive performance, animal health, environmental issues and availability of water and bedding in the region.

The Compost Barn system has found a wide spreading in Brazil in last years (Lobeck et al., 2017). However, in Brazil, there is still little information about compost barns and their respective characteristics that interfere with animal thermal comfort, as well as those related to the productive performance of cows confined in different ways. The building typology of the shed, as well as the ventilation system applied in the barn, are of great importance in the efficacy of climatisation. The thermal stress, especially of cows of breeds with high genetic potential for milk production, can be strongly influenced by these factors (Garcia, 2017).

The natural ventilation system is still widely used by most Brazilian farmers. In naturally ventilated Compost Barns, the building should be located in open areas to allow a proper functioning of natural ventilation (Damasceno, 2012). Oliveira et al. (2019), applying the technique of geostatistics, remarked that the thermal environment in compost barns is greatly influenced by the ventilation system adopted. Damasceno et al. (2019) used the technique of geostatistics to evaluate the distribution and spatial dependence of different environmental variables. Spatial distribution maps showed the occurrence of high variability of attributes and content within the animal facility. Thermal environment variables showed alert situations throughout practically the entire facility.

The facility should be located at a slight elevation of the surrounding terrain to prevent the wetting of the bedding during rainy periods and the raising of the relative humidity to undesirable levels (Janni et al., 2007).

However, artificial ventilation systems can be applied to improve the microclimatic conditions inside the barn favouring the removal of air humidity and excessive heat generated by animals. The choice of the climatic control system should consider the ability of the fan to provide good air discharge, its size, drive type, operation costs and purchase (Damasceno, 2012).

Taking into account the growing interest of Brazilian dairy farmers towards the compost barn system, it is necessary to obtain more information about the efficacy of different climatic control systems. The present work aims to compare the productivity during the winter season of dairy cows confined in two different building typologies.

MATERIALS AND METHODS

The trials were carried out in a commercial milk farm with two different solutions of compost barn: a closed-side shed with negative pressure ventilation (CBF) and an open shed with natural ventilation system (CBA). The facilities are located in the municipality of Cajuri, Minas Gerais (Brazil), altitude 670 m, latitude 20°46'41"S and longitude 42°48'57"W. The region has a tropical climate with an average annual temperature of 19 °C, characterized as Cwb (wet temperate climate with dry winter and temperate summer) by Köppen climate classification.

The closed barn has a polyethylene curtain closure, tunnel-style ventilation associated with the evaporative cooling system, composed of panels of porous cellulose material.

The closed barn (CBF) (Fig. 1) has a Northwest-Southeast orientation, 0.8 m eave galvanized steel roofing and it is closed with polyethylene curtains and deflectors. The pillars are made by reinforced concrete, spaced 5.5 m. The ceiling height of the shed is 5.0 m, the height to the ridge is 7.0 m.

The facility is 55 m long and 26.2 m wide, of which 16 m are for the bedding area. Inside, in addition to the bedding area, there is a 3.80 m feeding alley with a concrete floor. Four drinkers are placed in the feeding alley. Two corridors are present, one 4.0 m wide for the circulation of machines and one 2.40 m wide for service.

The sides of the barn have a fixed polyethylene curtain, while the southeast face has porous cellulose panels, with a surface area of approximately 11.52 m², which can be moistened for evaporative cooling. The northwest face of the installation has five exhaust fans (BigFan®, 3.5 m diameter, 150,000 m³ h⁻¹ air volume and 2.0 HP power) for tunnel-type ventilation. Humidification of the panels occurs when the air temperature



Figure 1. The closed compost barn (CBF) for dairy cows.

is above 21 °C and relative humidity below 75%. The facility has polyethylene curtains and nine deflectors.

In the resting area a mixture of sawdust and coffee husks is used as bedding, about 0.60 m thick. The bedding is cultivated twice a day. Approximately 88 Holstein cows in the lactation phase are housed in this shed, with a surface of 10 m² cow⁻¹ in the bedding area.

The open barn (Fig. 2) is also oriented in the Northwest-Southeast direction and it is covered with galvanized steel plates, with a 0.5 m eave. The ceiling height is 6.0 m, the ridge height is approximately 7.5 m. The ridge type used was overshoot. The facility is 60.0 m long and 20.7 m wide, of which space of 14.3 m is reserved to the bedding area. The barn has a feeding alley 4.25 m wide with slatted concrete floor and a 2.15 m wide corridor for animal handling. The facility has completely open sides. The bedding is made by sawdust and is cultivated twice a day. The height of the bedding is approximately 0.30 m. In this barn, 63 lactating cows are kept, with a surface/head of 13.6 m² in the bedding area and the specific building characteristics favour the natural ventilation.

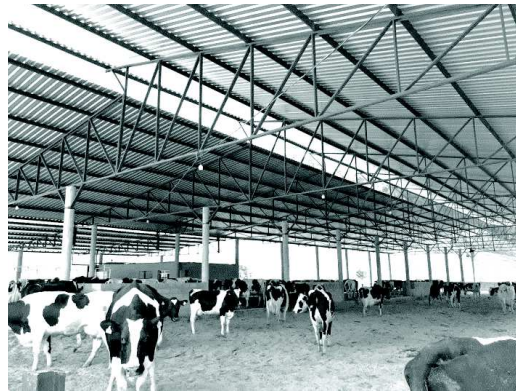
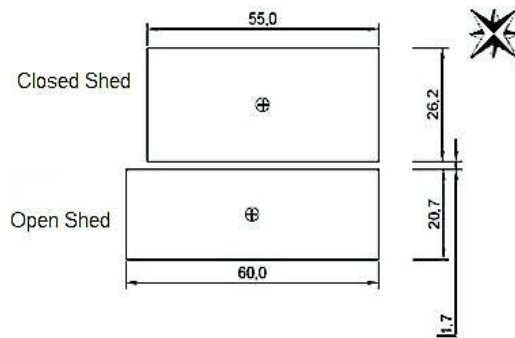


Figure 2. The open compost barn (CBA) for dairy cows.

HOBO® (Data Logger Ux100-003 – Onset) sensors were used to collect data of the temperature and relative humidity of the air inside the barns. They were placed in the central point of the shed, at the height of the centre of mass of the compost barn (Fig. 3). Sensors of the same type were employed to collect air temperature and relative humidity outside the sheds.

A sensor was installed in each barn to ensure that the entire area of both sheds were monitored in real time, so that the final values of the variables were the average representative of the internal thermal environment, 24 hours each day, as per methodology used by Barbeg et al. (2007).

Thermal data collection took place during winter (14 days of collection, on August 2019) and data were stored every 5 minutes, 24 hours a day, during the mentioned period.



where Tdb – Dry bulb temperature (°C);
Tdp – Dew Point Temperature (°C).

Figure 3. Schematic representation of the installation points of air temperature and relative humidity sensors (HOBO®) at the centre point of each compost barn.

Dry bulb temperature and dew point temperature, obtained by microclimatic data collected, were used to calculate the Temperature and Humidity Index (THI) by the Eq. 1 proposed by Thom (1959).

$$THI = Tdb + 0.36Tdp + 41.5 \quad (1)$$

Based on the THI data, daily graphs over the experimental period were made to analyse the daily thermal conditions and hourly averages and to define the most critical conditions for the animals.

Information regarding the milk production of each animal for each shed were obtained, based on production data collected by the PDPL (Viçosa Dairy Cattle Development Program) team, which monitors milk production of each animal of this unit regularly. The productivity data were referred to the litres of milk produced per animal per day, for groups of cows at first and second lactation (G1), third lactation (G2), fourth lactation (G3) and fifth lactation onwards (G4). During the experimental period for each barn, the average productivity data of each group were correlated with the average, maximum and minimum THI.

The average test was performed to test the interference of the environment represented by the THI on the productivity of each group of animals, and it was presented by tables and graphs. The data were compared using the Student's t test with the support of the R software (5% significance).

RESULTS AND DISCUSSION

Environment

Table 1 shows the values of average and maximum temperatures and daily THI for both types of barns.

The average hourly temperatures of the experimental period are shown in Fig. 4.

The thermal comfort zone for European dairy cattle breeds, where the animal has its optimal physiological performance, is located between -1 °C and 16 °C. Zones ranging from -10 °C to -1 °C and 16 °C to 27 °C are characterized by modest thermal comfort. At temperatures outside the mentioned zones, the animal already has certain thermoregulatory mechanisms for adjusting its body temperature (Baêta & Souza, 2010). Maximum temperatures above the limiting temperature above the zone of modest thermal comfort were observed.

Therefore, environmental influences may occur on the milk production of the cows.

Table 1. Daily maximum temperatures (T_{max}) and daily THI for the two types of compost barns, closed (CBF) and open (CBA)

Days	Closed barn		Open barn	
	T_{max} (°C)	THI	T_{max} (°C)	THI
Aug 06	21.82	65.97	21.42	65.68
Aug 07	26.24	65.68	24.63	65.50
Aug 08	22.35	64.17	25.02	64.43
Aug 09	25.75	63.06	27.49	63.65
Aug 10	25.34	64.67	27.31	65.23
Aug 11	26.95	65.05	29.90	66.07
Aug 12	25.31	62.33	27.27	63.00
Aug 13	26.02	64.52	28.77	64.95
Aug 14	23.12	65.97	21.20	65.11
Aug 15	21.63	61.14	20.85	60.74
Aug 16	22.16	58.22	23.31	58.42
Aug 17	22.02	57.07	23.31	57.08
Aug 18	25.24	60.49	26.92	61.00
Aug 19	31.49	63.79	30.96	64.27

The critical upper temperature established for lactating Holstein cows is 25 °C (Garcia, 2017). In the trials, temperatures above the maximum critical value for daytime comfort were observed, which may be responsible for behavioural and dietary changes in the animals during the studied season.

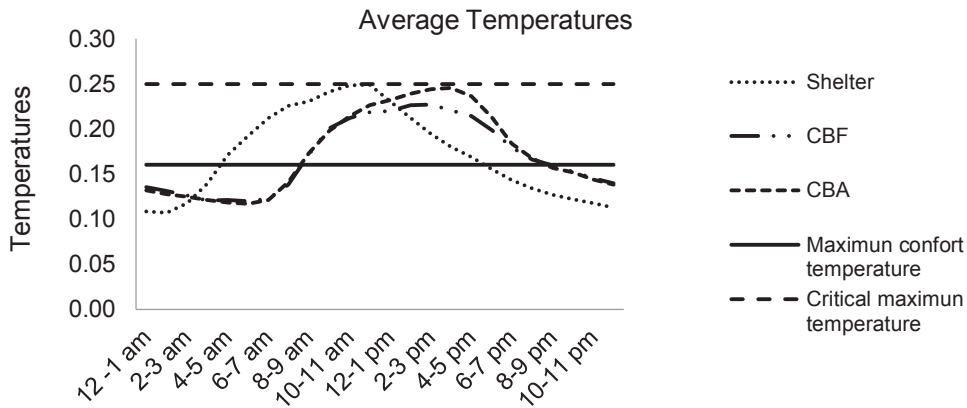


Figure 4. Average hourly temperatures in the two compost barns (closed, CBF; open, CBA) compared to the maximum comfort temperature and critical maximum temperature for dairy cows.

Regarding THI, ranges are used to determine and analyse animal comfort (THI less than or equal to 70: normal situation; THI between 72 and 78: warning situation; THI between 78 and 82: danger situation; THI above 82: need for immediate intervention) (Pires & Campos, 2004).

During the trials the THI values remained within the normal range, assuring comfort conditions for the cows. Fig. 5 shows THI during the experimental period allowing a visual comparative analysis on the thermal environment of the two types of barns.

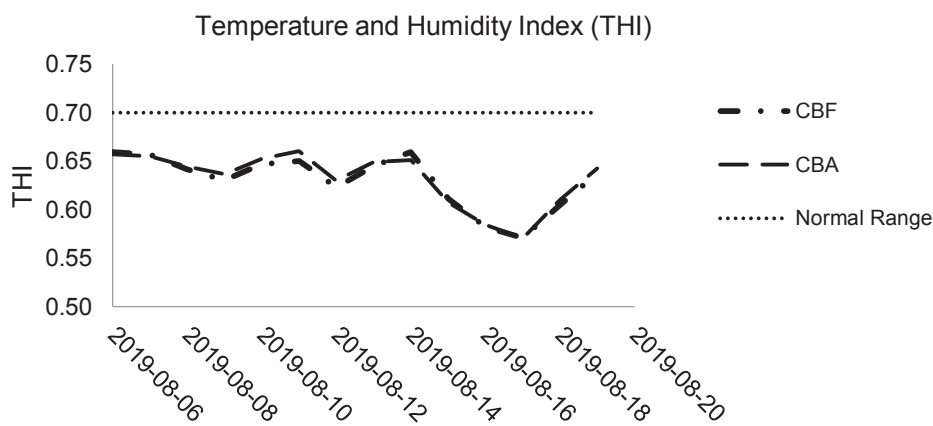


Figure 5. THI in the experimental period in the closed (CBF) and open (CBA) compost barns.

Productivity

Holstein cows at third and fourth lactation have higher milk yield compared to second lactation cows. From the fifth lactation a production fall is registered (Souza et al., 2010).

In order to exclude that the milk production could vary for the lactation order, the animals were divided into lots or groups of different lactations, being the group G1 for cows in first and second lactations, G2 for cows in third lactation, G3 for cows in fourth lactation and G4 for cows in fifth lactation onwards. Productivity analysis of cows housed in both facilities was performed and the results are shown in Tables 2, 3.

Studies show that yield for Dutch Friesian cows ranges from 23 to 44 kg of milk cow⁻¹ day⁻¹ (Deitos et al., 2010). Thus, the animals in the experimental groups, with the exception of lot 2 (G2) of the closed shed, produce according to standards described in the literature. In general, the most expressive values of milk production are presented for the animals confined in the open shed.

The average values of productivity per lot of animals are showed in Table 4, compared with the maximum, minimum and average indices of the experimental period.

Table 4. Average productivity data of the cows housed in both types of barns in relation to maximum, minimum and average values of THI

Group	Closed Barn (CBF)		Open Barn (CBA)		
	Productivity (L head ⁻¹ day ⁻¹)	THI (total)	Productivity (L head ⁻¹ day ⁻¹)	THI (total)	
G1	26.55a	Maximum 65.97	25.95a	Maximum	66.07
G2	21.58b	Medium 63.01	33.60a	Medium	63.22
G3	27.79a		34.50a		
G4	22.67a	Minimum 57.07	27.00a	Minimum	57.08

*averages followed by the same letter on the line do not differ statistically by the t-student test.

There was no statistically significant difference ($P > 0.05$) in relation to the average milk production between lots 1, 3 and 4 when the two facilities were compared. For lot 2, there was a statistically significant difference ($P < 0.05$), suggesting that the average production was higher for the open facility. In the studied conditions, during the winter, the closed barn did not obtain satisfactory results to justify its use, because both in construction and maintenance, this typology presents higher costs.

Table 2. Productivity average and standard deviation of the cows housed in the closed barn (CBF) for distinct groups classified by lactation orders

Group	Productivity (L head ⁻¹ day ⁻¹)	Standard deviation	Coefficient of variation
G1	26.55	9.64	36.32
G2	21.58	6.43	29.80
G3	27.79	8.13	29.24
G4	22.67	3.42	15.09

Table 3. Productivity average and standard deviation of the cows housed in the open barn (CBA) for distinct groups classified by lactation orders

Group	Productivity (L head ⁻¹ day ⁻¹)	Standard deviation	Coefficient of variation
G1	25.95	5.44	20.98
G2	33.60	7.03	20.91
G3	34.50	0.71	2.05
G4	27.00	4.24	15.71

CONCLUSIONS

The thermal environment inside the two compost barns, based on THI, was comfortable for the cows during the experimental period.

The thermal conditions inside the two different barns during the trials carried out in the winter season did not represent a factor influencing the productivity rates of dairy cows. The productive performance of animals housed in the open compost barn was slightly higher than that observed for animals housed in the closed compost barns.

In conclusion, the use of a closed barn with negative pressure ventilation is hardly justified as a system that favoured the productivity of the confined cows under the analysed conditions.

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