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Behavioural patterns of cows housed in two different typologies of compost-bedded pack barns

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Abstract. The compost-bedded pack barn (CBP) is an innovative housing technique which has the improvement of animal welfare as main objective. A comparative study of the behaviour of Holstein-Friesian dairy cows housed in two different compost-bedded pack barns located in the State of Minas Gerais (Brazil) was carried out during the winter season. One barn (CBP A) is closed and applies a wind tunnel ventilation (negative pressure). A second barn (CBP B) is open with natural ventilation, without curtains on the sides, and has fans placed in the resting area. Infrared video cameras were installed in the two barns to allow continuous and simultaneous monitoring of cows' behaviour. Air temperature and relative humidity inside the barns were monitored continuously and Temperature-Humidity Index was consequently calculated. The results show that the cows housed in the closed barn, with forced ventilation (CBP A), were in good thermal conditions, which were fairly constant, while in the open barn (CBP B) the internal microclimatic conditions were more subject to outside climatic conditions. A close relationship was found between the trend of air temperature and relative humidity inside the facilities and the behaviour of the cows. The number of cows at rest, in CBP B, decreased as the THI value rose. In CBP A, the behaviour of the cows in relation to THI was much more constant.

Key words: animal behaviour, compost bedded-pack barns, dairy housing, environmental conditions.

INTRODUCTION

The housing system for dairy cows based on compost bedding is very popular in Brazil. After the construction in 2011 of the first compost bedded pack-barn (CBP), a few thousands facilities have been built with this housing technique.

This loose housing solution today is known all over the world (Leso et al., 2020). The improvement of animal welfare for dairy cows is the main reason of the success of compost barns around the world (Black et al., 2013; Leso et al., 2013; Bewley et al., 2017; Mota et al., 2019). The compost barn system has demonstrated suitable results also in terms of improved hygiene and lameness scores (Costa et al., 2018; Pilatti et al., 2019), increased longevity of the cows (Leso et al., 2019), improved productivity per animal (Barberg et al., 2007; Black et al., 2013). Silva et al. (2019) found not significant economic differences between milk-production systems based on compost bedding and free stall, stating that management ease and bedding material availability could be decisive to choose one system over the other.

The CBP system consists of a wide covered space available for the cows with an open bedded pack area, useful for resting and exercise. Because the animals can walk freely within the barn, this system is also indicated with the name *Freewalk* (Bewley et al., 2017; Galama et al., 2020).

The building solution can be very simple, because it can be based just on a fully open structure with a roof. The completely open barn with natural ventilation is the solution generally adopted in Brazil. However recently some barns have been realized with a closed structure provided with a mechanical ventilation system and an evaporative cooling system (Andrade, 2020). Since the design of the building is fundamental for the achievement of acceptable productive results, it is necessary to deepen the analysis of the building solutions, which have to be considered in relation to the different climatic conditions. Therefore, the purpose of this work was to compare the behaviour of Holstein-Friesian cows kept in two different housing solutions, one based on natural ventilation in a completely open barn and one based on mechanical ventilation in a closed barn, in order to give useful suggestions in design and management of the barns.

MATERIALS AND METHODS

The study was carried out in a farm of Minas Gerais State (Brazil) with two different dairy barns in the winter season (July 7 – August 6, 2019).

One of the barns, housing lactating cows, is closed and applies a wind tunnel system. The other one, used for dry cows, is open with natural ventilation.

The closed compost barn (CBP A) housed during the trials 85 Holstein-Friesian lactating cows, in good health state. The average milk yield was 25.58 L cow^{-1} per day with a maximum of 47 L and a minimum of 6 L. The 30 fresh cows (first period after calving) had an average milk yield of 17 L cow^{-1} while the other 55 cows gave an average of 30.24 L cow^{-1}. The cows were milked twice a day, early in the morning and in the afternoon. The average body weight of lactating cows, taken on 18th July 2019, was 726.67 kg.

The barn is oriented in north-west / south-east direction. The facility has a length of 55 m and a width of 26.8 m. The total available area for cows (1,100 m^2) includes a bedding area (880 m^2) and a feeding area (220 m^2). The surface/head with 85 cows kept inside is 10.35 m^2 in bedding area and 12.94 m^2 totally (Fig. 1). The barn is 5 m high in eaves and 7 m high in ridge. The gabled roof is made by galvanized steel sheets. Curtains in polyethylene of blue colour are placed on the two main sides of the building. Inside the facility five deflectors are installed to address the air flow. The lighting of the barn is realized by led lamps (100 W) placed in the resting area and in the feeding alley.

An evaporative cooling system, consisting in five fibro-cellulose panels, is installed in CBP A in southeast side. The system works when the temperature rises above 21 °C with a relative humidity below 75%. Five fans (BigFan®), placed the northwest side, provide for the extraction of air from the building. The fans, 3.5 m diameter and 2.0 hp power, operate continuously 24 hours a day.

The open facility (CBP B) housed 24 Holstein-Friesian dry cows, in good health state. The average body weight of dry cows, taken on 18th July 2019, was 818.67 kg.

The barn is oriented in the same northwest - southeast direction. The available area for cows is 450 m^2 (25 m length, 18 m width), with a resting area of 350 m^2 and a feeding area of 100 m^2. The surface/head with 24 cows kept inside is 14.58 m^2 in bedding area and 18.75 m^2 totally (Fig. 1). The building is 5 m high in eaves and 7 m high in ridge. It is a completely open barn. The gabled roof is made by galvanized steel sheets and no curtains are installed on the sides. In the resting area, 3 circulation fans are placed to move the air towards the animals. A misting cooling system is installed in the feeding corridor.

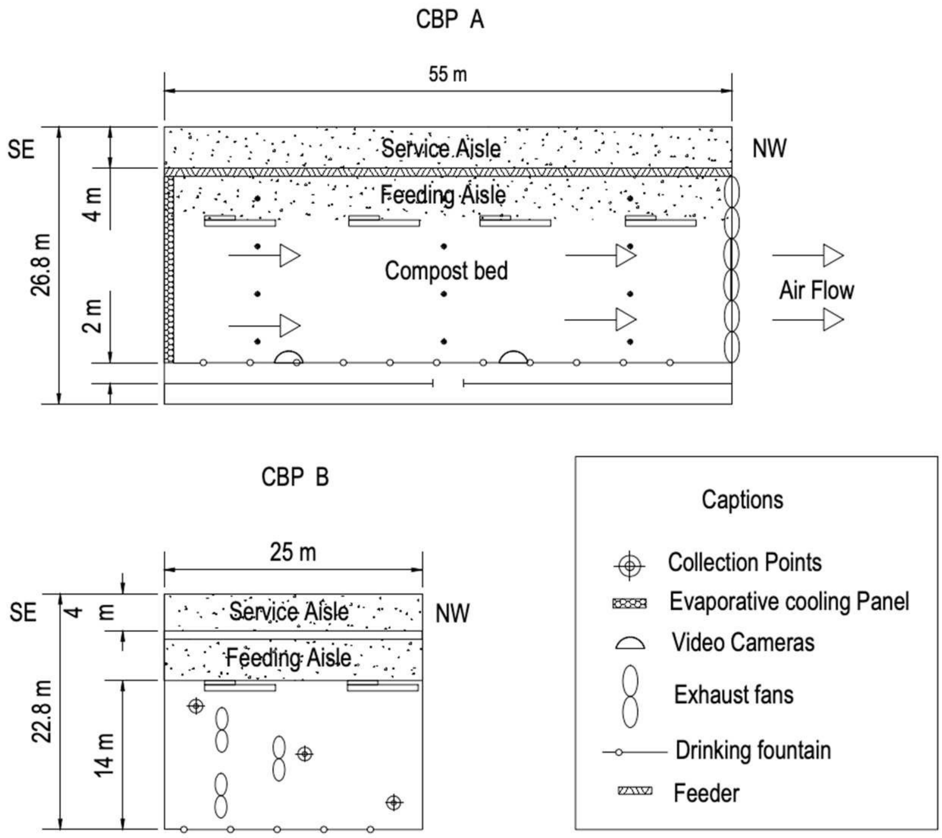

Figure 1. Layout of CBP A and CBP B.

A mix of coffee husk and dry sawdust is employed as bedding material in CBP A, with a thickness of 0.60 m. A tractor equipped with a chisel with roller is used twice daily to stir the bed, totally 18 min day^{-1}. New fresh and dry bedding material is added every 10 days about for a thickness of 5 cm, corresponding to a total of 44 m^3 (1.55 m^3 per head, month) to maintain under control the moisture level of the pack. The total renewal of the litter is carried out once a year. The amount of compost removed each year is a total of 528 m^3.

Also in CBP B a dry sawdust and coffee husk mix is employed as litter material, with a thickness of 0.30 m. The same tractor of CBP A is used to stir the bedding once daily (5 minutes). Fresh and dry litter is added every month, with a thickness of 3 cm, corresponding to 0.44 m^3 per head, month. The bedded pack is completely renewed once every two years (105 m^3).

During the trials data loggers were installed inside in the middle of each barn, at a height of 2.5 m, and outside, to measure air temperature (°C) and relative humidity (%) (HOBO® Data Logger Ux100-003 - Onset - USA; precision ± 0.21 °C temperature; ± 3.5% RH). The data loggers were programmed to measure and store at 5-minute intervals, 24 hours a day.

A number of spots was established inside and outside the barns, in order to acquire representative measures. In CBP A, the resting area was divided into 9 equal parts, while the feeding area was divided into 3 parts. In CBP B the division was in 3 equal areas for resting area and 1 area for feeding alley. Each environmental measure was taken in the centre of all spots, 0.1 m height above the litter (pack level) and 1.3 m height (animal level).

A dedicated video recording system with infrared cameras (VMI-CAM1782N-IRP-L3 with a minimum resolution of 420 lines, lens with a focal length of 3.6 mm, connected to a microcomputer through two 16-channel image capture cards) was installed in each barn to allow continuous monitoring of cows behaviour during all the day (24 hours, day and night): 4 cameras in CBP A, 1 camera in CBP B. These cameras were placed to collect images of the resting area and the feeding alley, in order to see all the cows inside the barns at any time. Video cameras recording was simultaneous in the two barns.

The videos obtained were transformed into images, in order to facilitate the counting of the animals thanks to the free software 'Free Video to JPG Converter v.5.0.101 build 201', downloaded on the internet. The program allowed capturing images every 20 seconds.

The data collection period (video recordings) was one week for each barn from July 29 to August 06. Within this period, 3 days were selected as most representative, so 72 hours recording was taken into consideration for processing. The images were selected with an interval of 5 minutes (288 images for 24 hours, for each camera).

To assess the level of heat stress of the cows, with reference to the temperature and relative humidity of the air, the temperature and humidity index, THI, was used. Several formulas exist for the evaluation of the thermal comfort inside the barns. The THI formula according to Mader et al. (2006) and taken as reference by the International Commission of Agricultural and Biosystems Engineering (Panagakis et al., 2009) was used:

$$\mathrm{THI} = (0.8\ x\ \mathrm{Tdb}) + \left[\left(\frac{\mathrm{RH}}{100}\right) x\ (\mathrm{Tdb} - 14.3)\right] + 46.4 \qquad (1)$$

Tdb = dry-bulb temperature (°C); RH = relative humidity (%); 0.8, 14.3 and 46.4 = constants.

Usually a THI of 74 or less is considered normal, 75 to 78 gives an alert status, 79 to 83 a danger status, and a THI equal to or above 84 indicates an emergency condition (Thom, 1959; Hubbard et al., 1999; Damasceno et al., 2019). However, already THI values above 72 could represent a stress condition for Holstein cows, which may lead to reduced productivity (Johnson, 1980).

Statistical analysis

The proportion of cows lying, feeding and standing have been calculated by dividing the number of animals presenting that specific behaviour by the total number of animals within the pen. Cows' behaviour and environmental measures have been collected at 5-minute frequency. Prior to the analysis, data have been grouped by hour. Statistical analysis has been carried out with R (R Core Team, 2019). A mixed model for repeated measures was built for behavioural response variables (lying, feeding, standing) as well as internal THI. All models included the fixed effects of barn and time. Fixed effect of THI was also included in the models for behavioural response variables. All second-order interactions were also tested. In all models, the random effects of hour and day have been included. Results are reported graphically with error bars representing +/- standard error of the mean.

RESULTS AND DISCUSSION

Air temperature and relative humidity, and consequently Temperature and Humidity Index (THI), have an influence on the behaviour of the cows on the barns. Fig. 2 shows that the THI in CBP A is significantly higher than in CBP B during the night and early morning (between 9 p.m. and 7 a.m.) while during the day (between 10 a.m. and 7 p.m.) THI in CBP A remains signifiantly lower than in CBP B. The extreme values give respectively 52 and 69 as minimum and maximum value of THI for CBP A and 50 and 72.5 as minimum and maximum for CBP B. These data in comparison with what results in literature (Thom, 1959; Hubbard et al., 1999) allow us to say that the cows are in thermal comfort conditions. Indeed, the maximum value of THI in the 2 barns is less than 74. But according to Johnson (1980), which sets the maximum comfort value at 72, it is possible to state that CBP B presents a discomfort situation at a peak around 3 p.m. with a THI value of 72.5.

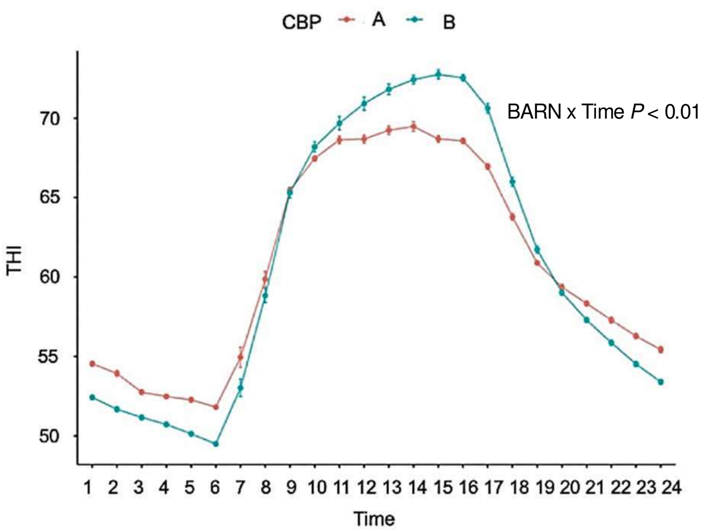

Figure 2. THI with the standard deviations of the two barns.

Fig. 3 and Fig. 4 refer to a day chosen as representative among the three days considered in the study (as reported in Materials and methods). They show that there is a close relationship between the trend of air temperature and relative humidity and the behaviour of the cows inside the facilities. In effect, the cows change their behaviour in relation to environmental conditions inside the barn (Barbari et al., 2010).

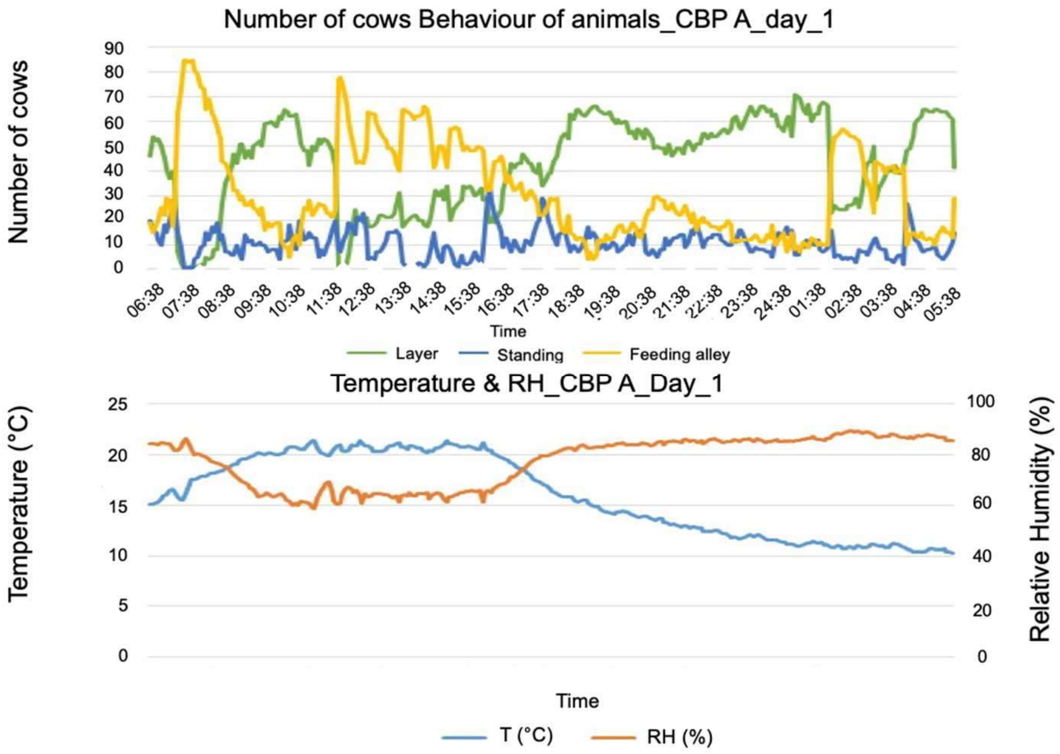

Figure 3. Behaviour of cows, air temperature and RH inside CBP A, Day_1.

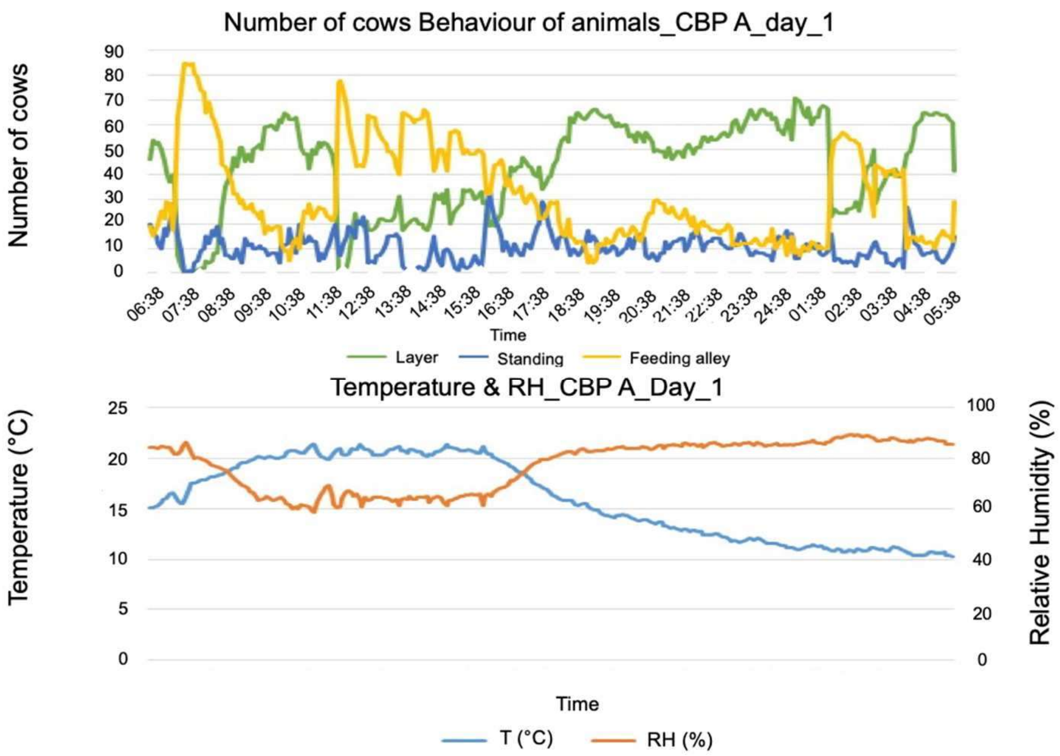

Figure 4. Behaviour of cows, air temperature and RH inside CBP B, Day_1.

A strict relationship between the environmental parameters and the activities of animals inside the barn was remarked in several studies. Provolo & Riva (2009) pointed out that the proportion of cows resting in freestalls during the day, unaffected by milking or feeding, goes from 30% in hot periods to 75% in winter. In other words, in cold conditions the cows stay longer in position of lying down, resting, during which time they ruminate the most. But when it is warmer, the animals are more inclined to stand up, to look for the cooler places in the barn, such as the feeding aisle, which often has a cooling system, to find comfort, rather than lying down. This is confirmed by Perissinotto et al. (2006) which found that the cows spend more time near the sprinkling systems, especially in the feeding area.

The way cows behave during the day is strongly linked to their state of comfort or non-comfort, as can be seen from Figs. 5–7, which relate behavioural trends to THI in the two facilities.

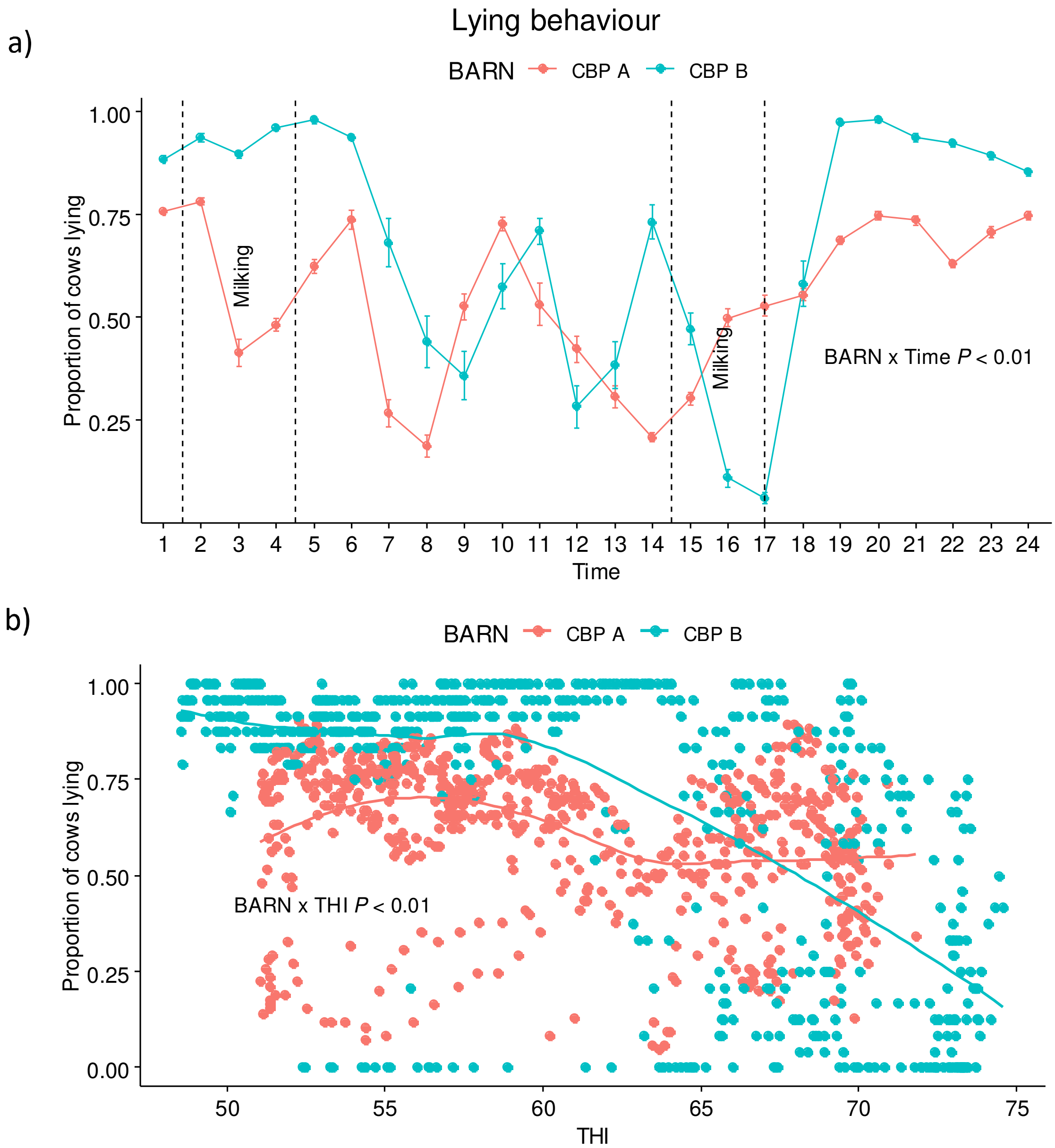

Figure 5. Interaction effect of barn x time (a) and barn x THI (b) for laying behavior.

Analysis of cows' behaviour highlighted that the interaction of BARN x Time significantly affected lying time (Fig. 5, a). Overall, cows in CBP B spent more time lying than those in CBP A ($P < 0.01$). The difference between CBP A and CBP B in the proportion of cows lying is particularly evident during night and early morning (between 7 p.m. and 8 a.m.). During daytime (between 9 a.m. and 6 p.m.), when animals tend to be more active, inconsistent differences in laying time were found.

Lying time was also affected by BARN x THI interaction (Fig. 5, b). Cows in CBP B showed to rest more than cows in CBP A at low THI. The proportion of cows lying in CBP B decreased rapidly with increasing THI while lying behaviour of cows in CBP tended to remain stable across a wide range of THI.

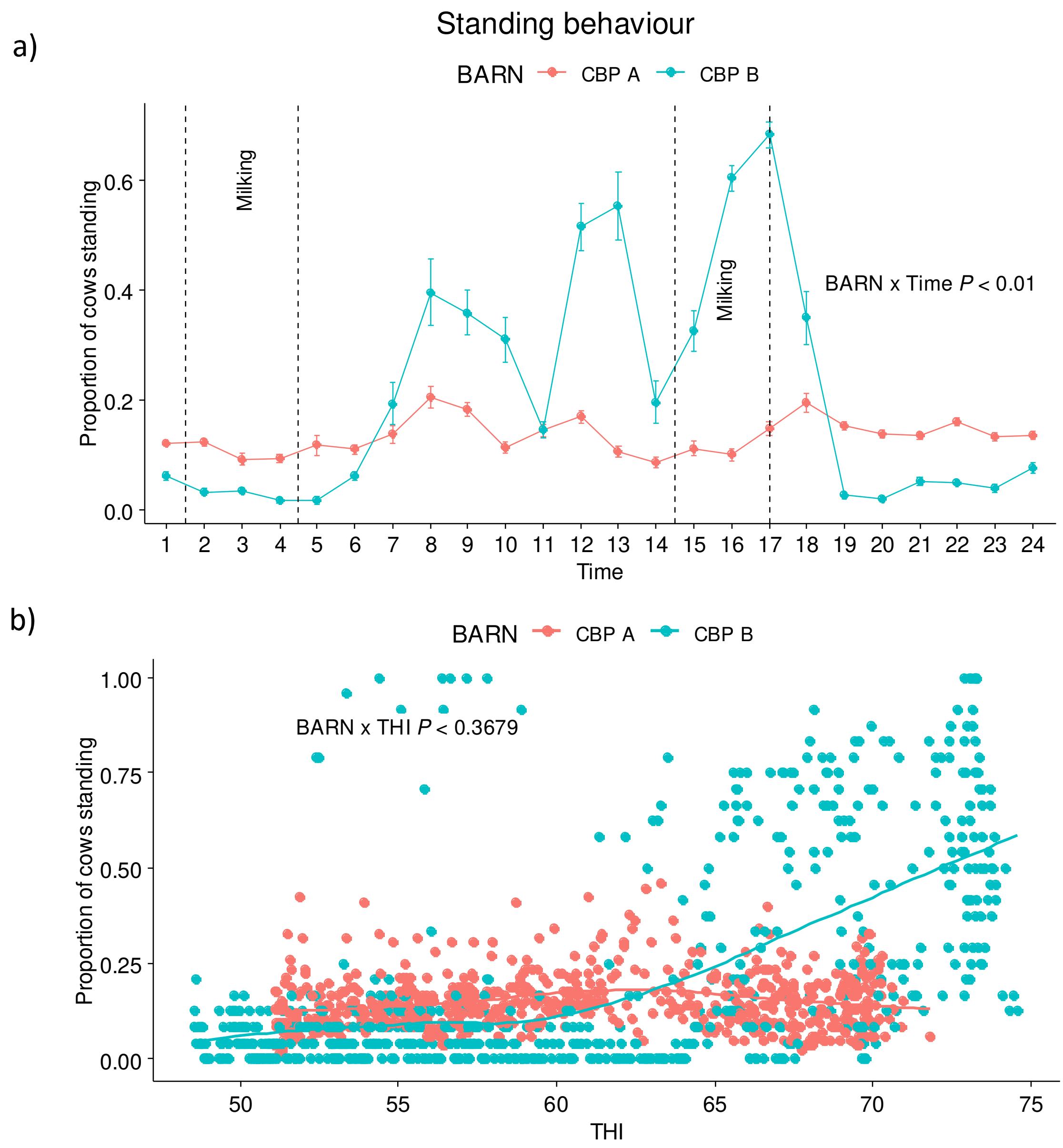

Figure 6. Interaction effect of barn x time (a) and barn x THI (b) for standing behaviour.

Analysis of standing behaviour also revealed a significant BARN x Time interaction (Fig. 6, a). On average, cows in CBP B spent significantly more time standing than those in CBP A ($P < 0.01$). However, like for resting behaviour, the difference in standing time varied throughout the 24 hours. A higher proportion of standing cows was recorded in CBP B than in CBP A during the daytime (between 7 a.m. and 6 p.m.) while the opposite occurred during the night (between 7 p.m. and 6 a.m.). Overall, standing time tended to increase with increasing THI ($P = 0.076$). Even though the interaction BARN x THI was not statistically significant, the standing behaviour of cows in CBP B showed to be more susceptible to variations in THI compared to CBP A, where standing behaviour seemed to be unaffected by THI (Fig. 6, b).

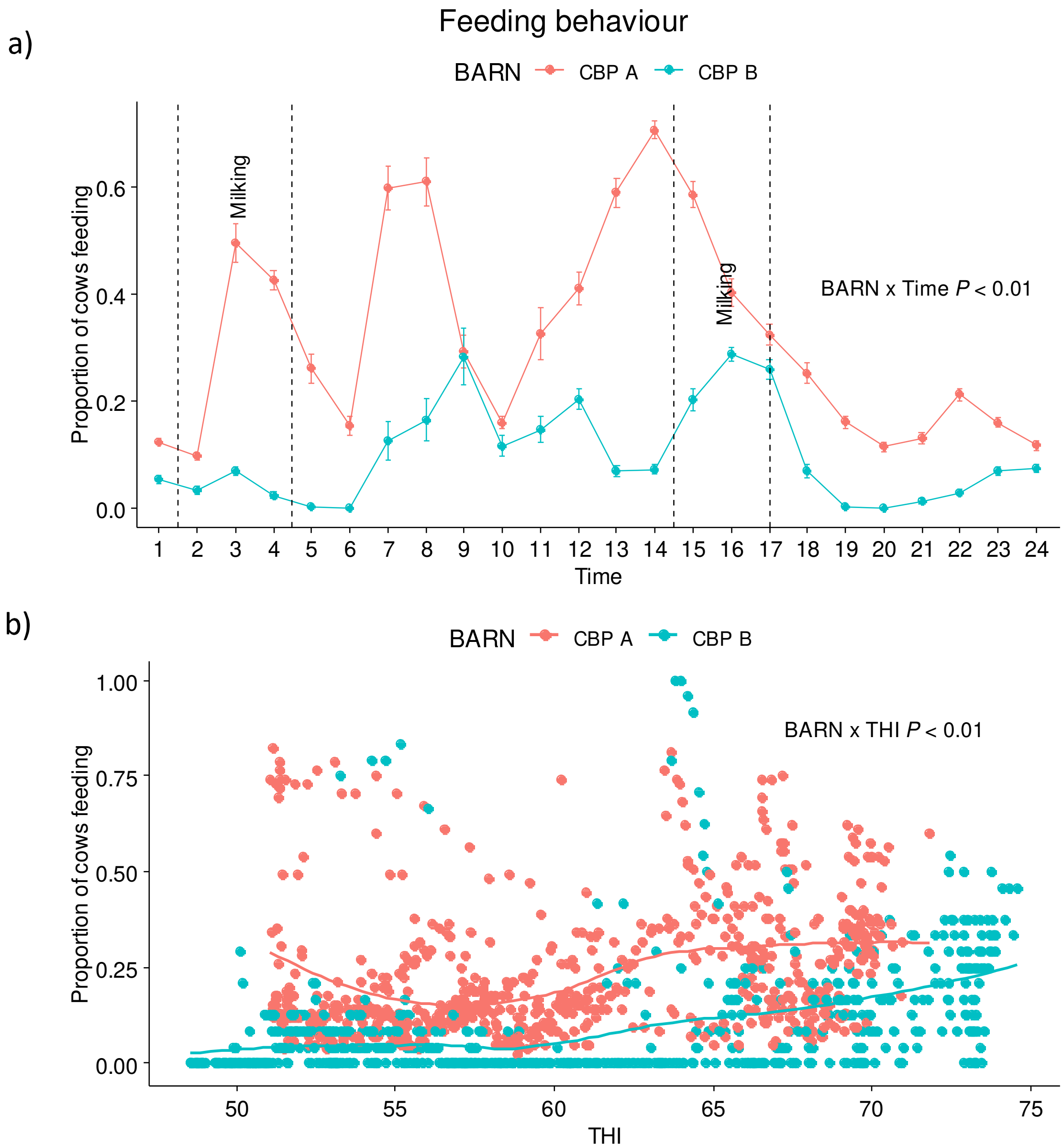

Figure 7. Interaction effect of barn x time (a) and barn x THI (b) for feeding behaviour.

The model fitted for feeding behaviour showed that cows in CBP A spent consistently more time eating than those in CBP B ($P < 0.01$). As for both resting and standing, the BARN x Time interaction significantly affected feeding behaviour (Fig. 7, a). The difference between the two barns in the proportion of cows feeding was wider during the daytime than during the night. In both barns, the proportion of cows feeding increased with increasing THI ($P = 0.011$). The effect of THI on feeding time differed between the two barns as showed by the significant BARN x THI interaction (Fig. 7, b). In CBP B feeding time increased with increasing THI whereas feeding behaviour of cows in CBP A remained rather stable across various levels of THI.

A comparison of the graphs which compare the behaviour of the cows and the THI values confirms that for lower THI values the tendency of cows to be in rest position than in standing position is higher and vice versa for high THI values. This is more noticeable for CBP B than for CBP A which has a climate control system. In other words, when the cows are in thermal comfort, they prefer to rest. This is confirmed by several authors including Leso et al. (2020) who say that with THI < 72 cows rested longer and walked less (12.7 h d^{-1}, 71.6 steps h^{-1}) than with THI ≥ 72 (7.90 h d^{-1}, 120.8 steps h^{-1}).

CONCLUSIONS

The results show that the cows housed in the closed barn, with forced ventilation, in winter season were in good thermal conditions, which were fairly constant, while in the open barn the internal microclimatic conditions were more subject to environmental climatic conditions.

A close relationship was found between the trend of air temperature and relative humidity inside the facilities and the behaviour of the cows. The number of cows at rest, in CBP B, decreased as the THI value rose. In CBP A, the behaviour of the cows in relation to THI was much more constant.

A good layout and management can allow this innovative compost-bedded pack system to achieve its objectives. This essentially consists of a good control of moisture of the bedding by cultivating it regularly, with the continual supply of new material for the bedding, in sufficient quality and quantity, and an adequate space given to the cows (not less than 10 m^2 cow^{-1}). An appropriate control of microclimatic conditions inside the barn is fundamental to guarantee good welfare of the cows, as proven in this study based on the analysis of behavioural patterns.

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