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Spatial variability of methane and carbon dioxide gases in a Compost-Bedded Pack Barn system

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Abstract. The dairy sector significantly contributes to global food production, however, it is closely associated with environmental concerns, specifically the emission of greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2). The research problem focuses on the environmental impact of livestock farming, particularly in relation to the emission of greenhouse gases (GHG) such as methane (CH_4) and carbon dioxide (CO_2). Therefore, the objective of this paper was to assess the spatial variability of CH_4 and CO_2, as well as the thermal environment through the Temperature and Humidity Index (THI) and of air velocity (V, m s^{-1}) in a Compost Bedded Pack (CBP). The experiment was carried out in October 2023, in a commercial dairy cattle facility measuring 54×22×4.5 m (length×width×height) that housed 80 lactating cows. Measurements were collected at 75 points, 0.25 m above the bedding, for one minute in each point. To characterize the distribution of gases and the thermal environment, the data were underwent geostatistical techniques and kriging maps. THI values ranged from 72.4 to 78.4, categorizing the animals into two environments within the facility, comfort and alert to thermal conditions. The maximum recorded for CO_2 was 713.60 ppm in the region with a low ventilation incidence. CH_4 reached a ranging from 103.38 to 196.73 ppm in areas with low ventilation and higher temperatures. The use of geostatistics enabled the characterization of spatial variability of greenhouse gases CH_4 and CO_2, as well as THI and V. Analyzing these variables is crucial for implementing mitigation actions and developing an increasingly sustainable production system.

Key words: animal welfare, dairy cattle, gas monitoring, geostatistics, greenhouse gases.

INTRODUCTION

In the 21st century, we face crucial challenges in attempting to reduce emissions and control the accumulation of greenhouse gases (GHG) in the atmosphere (Su et al., 2020). In this scenario, livestock farming significantly contributes to climate change.

Studies indicate that livestock farming is responsible for 14.5% of anthropogenic greenhouse gas emissions in the atmosphere, with dairy cattle contributing to 20% of total gas emissions produced in livestock farming (Gerber et al., 2013; Singaravadivelan et al., 2023).

Methane (CH_4) and carbon dioxide (CO_2) represent some of the main GHGs emitted by ruminants primarily generated through enteric fermentation, feed production, manure production, and management (Naranjo et al., 2020).

In contemporary dairy farming, intensive housing systems are commonly adopted as strategies to mitigate heat stress, improve milk quality, ensure herd health, and increase animal productivity (Frigeri et al., 2023b).

In Brazil, an intensive system that has aroused the interest of dairy producers is the Compost Barn system (Black et al., 2013). This system seeks to meet the demand for animal welfare, featuring a large common area covered with bedding made of soft and comfortable material (sawdust or wood shavings), where the animals remain free to lie down and move, expressing their natural behaviours (Damasceno, 2020). However, high humidity and inadequate composting can lead to dirty cows, risk of bovine mastitis, reduced comfort and gas emissions due to the continuous accumulation of decomposing organic material (Blanco-Penedo et al., 2020; Leso et al., 2020; Emanuelson et al., 2022; Fuertes et al., 2023).

In intensive housing systems for dairy cows, gas emissions can be influenced by regional climate conditions and the housing system employed, particularly those without mechanical ventilation. In such systems, the decomposition of waste and gas emissions depend on the gradient formed by external variables, including air temperature (t, °C), relative humitidy (RH, %), and air velocity (V, m s^{-1}) (Ngwabie et al., 2009; Ding et al., 2016).

Although in the literature there is no specific reference addressing harmful CH_4 concentrations, it is essential to consider the potential adverse effects of CH_4 exposure on animal health. Excessive production of CH_4 in the enteric fermentation process in ruminants may indicate a lower efficiency in converting feed into usable energy by animals (Haque, 2018; Honan et al., 2022). This can negatively impact animals' productivity, as this energy could be used for growth, milk production, or weight gain (Lôbo et al., 2017; Pragna et al., 2018). In terms of climate effects, CH_4 emissions could become a global problem, due to its contribution to climate change, highlighting its importance even at low concentrations. (Niero et al., 2020). Despite CH_4 being more impactful for global warming, it does not persist in the atmosphere as long as CO_2 (Sejian et al., 2015), which is a natural component of the air and part of the animal respiration process (Zou et al., 2020).

High concentrations of CO_2 can cause irritation in the respiratory tract of animals, compromising the well-being and sustainability of the dairy industry (Stokstad et al., 2020). Moreover, in confined environments with inadequate ventilation, CO_2 accumulation can contribute to thermal stress, leading to reduced food and water intake and thereby adversely impacting the general performance of the animals (Pereira et al., 2013).

For dairy cattle, the concentration of CO_2 that is harmful to their health is not specified; however, when inhaled in large quantities, CO_2 can cause irritation in the airways, vomiting, nausea and death from asphyxiation (Damasceno, 2020). Ostovic et al. (2017) mention that CO_2 is present in the atmosphere at a concentration of

300–400 ppm. For agriculture, the concentration of CO_2 in the atmosphere affects carbon storage in the soil and microbial populations (Yu & Chen, 2019; Baveye et al., 2020).

In addition to direct impacts on animal health, CH_4 and CO_2 emissions contribute to the carbon footprint of animal production and have environmental implications, especially regarding climate change (Gerber et al., 2013). Elevated levels of CH_4 and CO_2 promote heat retention in the Earth's atmosphere and elevate global temperatures. This phenomenon has far-reaching consequences, including altered weather patterns, rising sea levels, ocean acidification, and impacts on animal health (IPCC, 2014; Beauchemin et al., 2020).

In this context, precision livestock farming, through detailed monitoring of animals and the environment, aims to discover non-invasive methods for evaluating animal production systems, such as using livestock indices and analyzing gas emissions (Cruz et al., 2023; Siegford et al., 2023), with the goal of enhancing decision-making and welfare control for confined animals.

Among the techniques employed by several researchers is the application of geostatistics, which investigates the spatial variability of variables, such as the distribution of GHGs, by extracting and organizing available data based on the similarity between neighboring georeferenced points (Ferraz et al., 2020; Andrade et al., 2022; Oliveira et al., 2023). This approach facilitates comprehension of the collected data and their influence on the animals' development environment.

Taking into account these factors and with the aim of providing valuable information about the distribution of these gases and their relationship with thermal conditions within the installation, the primary objective was to assess the spatial variability of the greenhouse gases CH_4 and CO_2 in a Compost Barn. Additionally, it aimed to characterize the thermal environment through the Index of Temperature and Humidity (THI) and air speed (V, m s^{-1}).

MATERIALS AND METHODS

The experiment was conducted in October 2023, in a Compost Barn-type facility for dairy cattle, located in the municipality of Lavras/MG, Brazil, at an altitude of 920.62 m and geographic coordinates 21°15' South latitude and 45°09' West longitude.

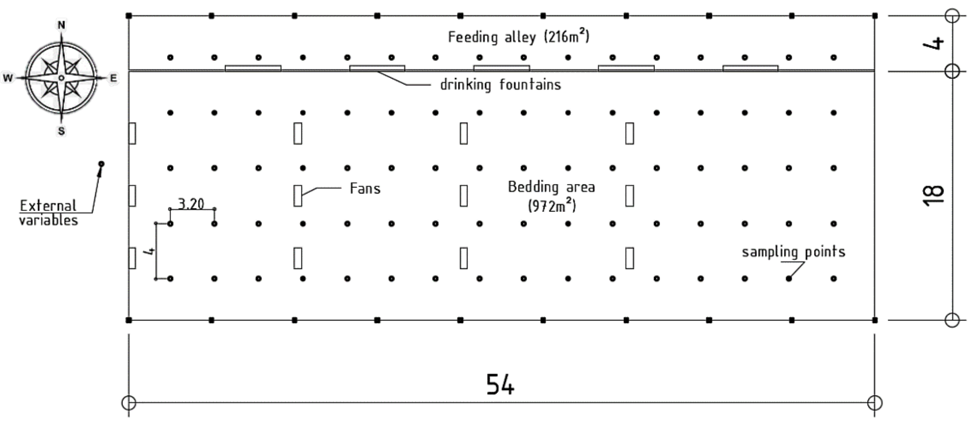


Figure 1. Schematic diagram com as dimensions (meter) and arrangements of points collected in the Compost Barn.

The facility is oriented from East to West and measures 54×22×4.50 m (length×width×ceiling height), including the integrated four-meter feeding alley, located on the North side (Fig. 1). The facility is open, without sidewalls, and there is a roof constructed of galvalume tiles with a 30% slope. Additionally, there are eaves extending three meters on the North and South sides, and one meter long on the East and West sides.

The Compost Barn system is an open, freely accessible facility for animals to rest and feed, a bedding area of 7.9 m^2 to 9.3 m^2 per animal, variable according to breed (Bewley et al., 2012). The studied facility holds 80 lactating cows, at a density of 1 cow/12.15 m^2, which remained throughout the data collection period.

The compost bed consists of sawdust, measuring 65 cm deep. The bedding material is turned over twice daily during this time of year (spring). The bed volume is restored according to the level reduction and removal after one year of use (Fig. 2).

Figure 2. West side view of the Compost Barn.

Mechanical ventilation occurs from the West to the East, aided by 12 fans positioned 2.5 meters above the bed and arranged in four lines. The Ziehl-Abegg® axial fans operate at high speed and low volume (LVHS), with a diameter of 1.10 m, three propellers, rotation 950 rpm, power consumption of 0.86 kW, and an airflow of 23.000 m^3 h^{-1}. The data was collected without any interference in farm management; therefore, the fans remained on throughout the process.

Data collection was asynchronous, starting at 7:00 AM and ending at 10:30 AM. For each point, data were collected for one minute, with intervals of ten seconds for each recording. The data collection height was 0.25 meters above the sawdust bed (Fig. 3).

The sampling grid points comprises 75 points, spaced 3.40 meters apart longitudinally and 4.00 meters apart laterally within the facility (Fig. 1).

Figure 3. Support fabricated for fixing the sensor at a height of 0.25 m.

The dry bulb temperature (t_{db}, °C), dew point temperature (t_{dp}, °C) and relative air humidity (RH, %) were logged by the datalogger Hobo® MX2301A, with precisions of 0.2 °C and 2.5%, respectively. Air velocity (V, m s^{-1}) was measured using a propeller anemometer, KR-835, with a measuring range of 0.4 to 30 m s^{-1} and a resolution of 0.1.

To record methane (CH_4, ppm) and carbon dioxide (CO_2, ppm) gases, a multi-sensor platform with a modular design and flexible architecture was employed. This platform is equipped with low-cost sensors that have been tested and calibrated in the laboratory (Fig. 4).

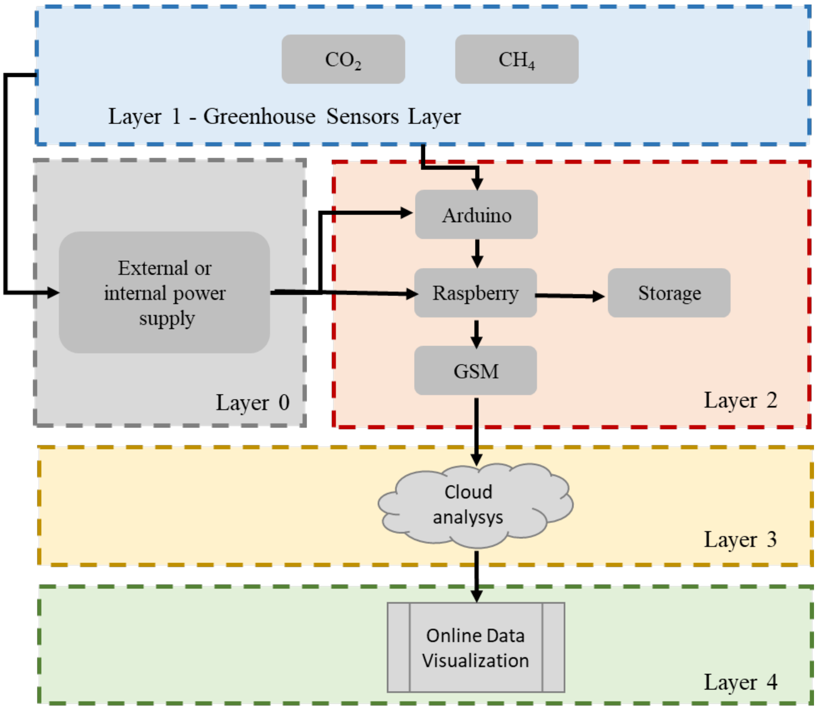


Figure 4. Layer organization of the system architecture (adapted from Becciolini et al., 2022a).

The entire multi-sensor platform design comprises four modules: gas measurement units, processor, server and dashboard. The processing unit includes an ARM Cortex M0+ core, ATM2560 microcontroller for data processing and transmission, and a Raspberry Pi Compute module. Low-cost commercial sensors, selected to meet the monitoring objective, have technical characteristics summarized in Table 1.

Table 1. Technical characteristics of the tested sensors

Target measurement	Sensor name	Type of sensor	Measurement range	Accuracy
CH_4 (ppm)	IRC-AT	Eletrochemical	200–10,000	± 100 ppm
CO_2 (ppm)	SCD30	NDIR	400–10,000	± 30 ppm

The thermal variables (t_{db}, t_{dp}, and RH) were also recorded externally from the Compost Barn using a Hobo® MX2301A datalogger. It was positioned one meter from the West face and at a height of one meter from the ground. Air velocity (V, m s^{-1}) was measured using a propeller anemometer, KR-835, which has a measuring range of 0.4–30 m s^{-1} and a resolution of 0.1. The assessment of the thermal environment was determined using the temperature and humidity index (THI) equation, developed by Thom (1959):

$$\text{THI: } t_{db} + 0.36\ (t_{dp}) + 41.5 \qquad (1)$$

where THI is temperature and humidity index (dimensionless); t_{db} is the dry bulb temperature (°C); t_{dp} is the dew point temperature (°C).

To obtain the spatial variability of CH_4 and CO_2 gases, and the environmental variables of the THI and V inside the Compost Barn, geostatistical analysis was applied, using the software R DEVELOPMENT CORE TEAM (2022). The semivariance was estimated by equation 2, described by Bachmaier & Backes (2008):

$$\hat{\gamma}\ (h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [Z(Xi) - Z(Xi + h)]^2 \qquad (2)$$

where $N(h)$ is the number of experimental pairs of observations $Z(Xi)$); and $Z(Xi + h)$ are positions separated by a distance h.

Semivariance adjustments and interpolation by ordinary kriging were applied to verify the dependence and visualize the spatial distribution. The method adopted was restricted maximum likelihood (REML), which results in less biased estimates (Ferraz et al., 2019).

The mathematical model used to adjust the semivariance was Gaussian. The parameters nugget effect (C_0), contribution (C_0 + C_1) and range (a) were obtained from the semivariance equation adjusted according to the behaviour of the graphs.

The quality of the fit was assessed by the degree of spatial dependence (DSD) according to the classification that considers values greater than 75%, a weak spatial dependence; values between 25% and 75%, a moderate spatial dependence; and values below 25%, a strong spatial dependence (Cambardella et al., 1994).

The choice of method applied can be reinforced by cross-validation, to compare the predicted values with the observed value, thus obtaining the mean error (ME), standard deviation of the mean error (SDm), reduced error (RE) and the standard deviation reduced error (SDR) (Ferraz et al., 2020).

The spatial distribution patterns of variables in the facilities were generated by maps plotted using Surfer® 13 software. These maps predict, through interpolation and spatial dependence, the value of a variable at a non-sampled point, based on a set of information obtained at other points.

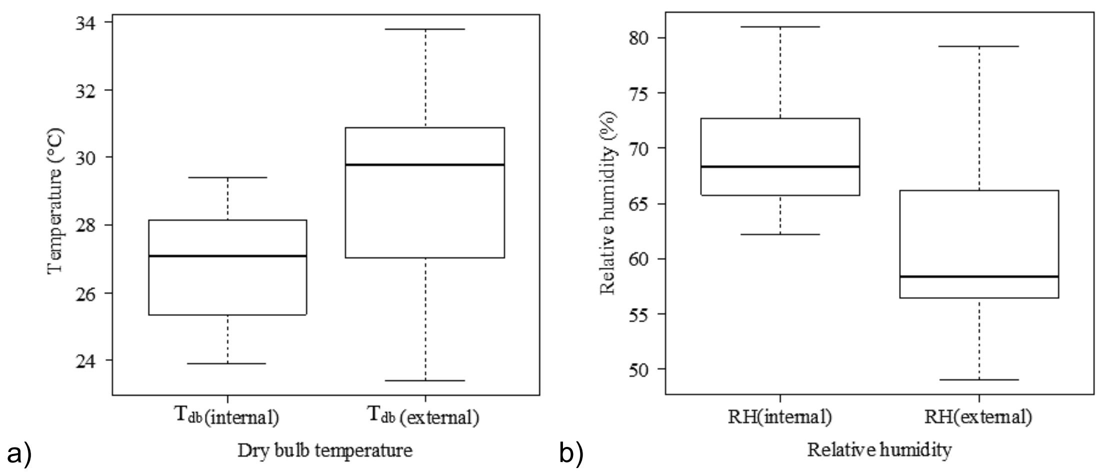
RESULTS AND DISCUSSION

Understanding the variability of thermal variables enables the identification and management of the thermal stress occurrences within the facilities. Therefore, Fig. 5 presents these results, comparing the internal variables (t_{db}, RH, and V) to the external variables during the experimental period.

According to Fig. 5, the three thermal variables studied (t_{db}, RH, and V) exhibited discrepant values when comparing the internal and external environment of the facility.

The t_{db} measured inside the Compost Barn registered an average of 26.9 °C while the external t_{db} registered one average of 29 °C (Fig. 5, a). The average temperature indoors draws attention to the need for additional strategies to control environmental variables, such as relative humidity and mechanical ventilation. The environmental temperature limit at which cows can regulate their temperature through metabolic processes is 27 °C; temperatures above this threshold are considered critical, compromising both well-being and productivity (Broucek et al., 2009).

The uncontrolled increase in the facility's temperature exposes the animals to thermal stress conditions, leading to behavioural changes (Becker & Stone, 2020). The primary behavioural changes observed in cattle include reduced time spent resting on the bed, decreased feed consumption, and increased time spent standing, walking, or at the water fountains (Frigeri et al., 2023a).



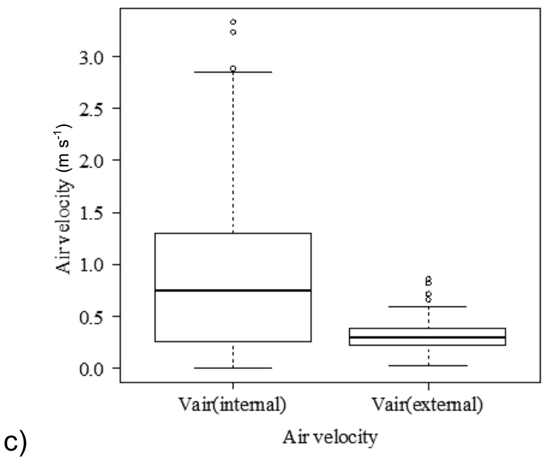


Figure 5. Distribution of internal and external thermal variables during the evaluated period: (a) dry bulb temperature (t_{db}, °C), (b) relative humidity (RH, %), and (c) air velocity (V, m s^{-1}).

In Fig. 5, b, it is observed that the internal RH registered an average of 69.7%, while the average of the external RH was 61.9%. In the internal environment, the predominance above 69.7% reinforces the need for a good ventilation system within the Compost Barn, since the maximum limit considered for animals is 70% (Ferreira, 2016). For situations where relative humidity is greater than 70%, only the use of ventilation allows good dissipation of the heat released by the animals through convection (Baêta & Souza, 2010).

In the Compost Barn production system, RH also directly affects the bedding where the animals lie. In this case, turnover strategies for the bedding material are adopted to reduce its humidity, which should ideally range between 40 and 65% (Shane et al., 2010). These strategies involve incorporating animal waste, which promotes microbial activity in the aerobic composting process (Leso et al., 2020).

Regarding the variable V, based on Fig. 5, c, it is observed that the greatest variability occurred inside the installation, where the average recorded was 0.99 m s^{-1}, while externally the average recorded was 0.32 m s^{-1}. High speed within the facility is desired and results from mechanical fans that provide high rotational speed and low entrained air volume (LVHS). However, most of the time the V was between 0.26 and 1.3 m s^{-1}. For Compost Barn type production systems, V must be maintained close to 1.80 m s^{-1} throughout the installation area, encouraging thermal exchanges, allowed drying of the bed and gas removal (Black et al., 2013).

It is plausible that the climatic variables, t_{db}, RH and V, influence both the physiology of the animals and the indices, and dispersion of gases within the installation. To access the dispersion of these variables and gases within the CBP, geostatistical analysis was applied, allowing the magnitude and spatial dependence of the microclimatic variables to be quantified, as shown in Table 2.

Table 2. Parameters estimated by the REML method and Gaussian model of the experimental semivariograms for the variables: Methane (CH_4), Carbon Dioxide (CO_2), Temperature and Humidity Index (THI) and Air velocity (V, m s^{-1})

Variable	C_0	C_1	$C_0 + C_1$	a	a'	DSD	ME	SDm	RE	SDR
CH_4	256.45	1,736.09	1,992.54	6.78	11.74	12.87	0.259	0.005	25.945	1.076
CO_2	1,170.60	8,296.02	9,466.62	24.99	43.25	12.37	-0.200	-0.003	37.611	1.020
THI	0.10	2.64	2.74	18.85	32.63	3.59	0.001	0.001	0.359	1.015
V	0.44	0.49	0.93	16.47	28.50	47.21	-0.003	-0.002	0.699	1.001

C_0 – Nugget effect; C_1 – Contribution; $C_0 + C_1$ – sill variance; a – range; a' – practical range; DSD – Degree of spatial dependence; ME – Mean error; SDm – Standard deviation of the mean error; RE – Reduced error; SDR – Standard deviation of reduced error.

The parameters of the experimental semivariograms adjusted to the Gaussian model using the REML method (restricted maximum likelihood) presented satisfactory results. Where the ME and RE should presenting values close to zero (Ferraz et al., 2020). Furthermore, the adjustments were satisfactory for all variables, the SDm value should result in the lowest possible value, and the SDR should present the closest value to 1.0. Although CH_4 and CO_2 exhibited RE values that were not proximate to zero, they demonstrated satisfactory values for the other three error evaluation metrics studied, thus characterizing them as well-fitted adjustments.

The nugget effect (C_0) is an important parameter that indicates the discontinuity of the semivariogram for distances smaller than the shortest distance between samples (Ferraz et al., 2017). The variables surveyed presented different C_0 values, which may be due to the fluid characteristics of each. The nugget effect occurs due to small-scale variability not captured by sampling, measurement errors, local variations, among others, without the possibility of individual quantification of the magnitude of these components (Oliveira et al., 2021).

According to Cambardella et al. (1994), the gases CH_4 and CO_2 as well as the THI presented a strong DSD, and the air speed variable presented a moderate DSD, that is, the variables present spatial dependence.

Practical range values obtained from semivariograms represent the distance within which samples are spatially correlated (Ferraz et al. 2017). All variables presented a practical range greater than the shortest distance sampled (3.4 m), with CO_2 having the greatest range (43.25 m) and CH_4 having the smallest recorded range (11.74 m). With this, it is possible to establish that distances greater than that used in this sampling can be considered (Oliveira et al., 2021).

To construct spatial distribution maps (isocolors), the values of the variables were estimated using ordinary kriging. In this way, the maps made it possible to visualize the spatial variability of the THI index, the variable V and the gases CH_4 and CO_2 (Fig. 6).

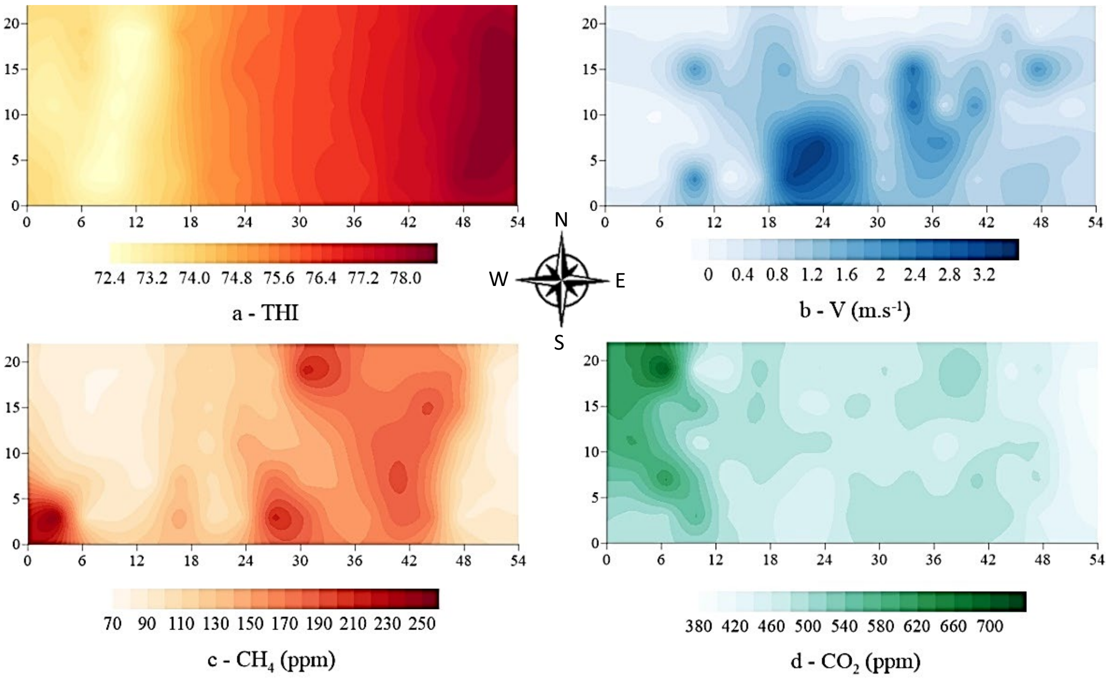


Figure 6. Spatial distribution of variables, where the X-axis represents the length (54 meters) and Y-axis represents the width (22 meters): (a) Temperature and Humidity Index (THI – dimensionless); (b) air speed (V, m s^{-1}), greenhouse gases concentration; (c) CH_4 (ppm) and (d) CO_2 (ppm).

The THI brings together in its formula the effect of two climatic properties, being widely applied to verify the thermal comfort conditions in which animals are subjected (Frigeri et al., 2023a).

In this study, THI values ranged from 72.4 to 78.4 throughout the entire experimental period. Reference ranges for cattle classify values below 74 as ideal conditions for thermal comfort; between 74 and 79 as a warning for producers; between 79 and 84 as dangerous conditions requiring safety measures to prevent losses in the herd; and greater than 84 as an emergency situation (Mader et al., 2006).

In Fig. 6, a, the yellow regions, primarily located on the west side of the facility, denote the lowest THI values, suggesting that the animals were within a comfortable range (below 74). There is an observed trend of increasing THI values along the length of the barn towards the East. As the shades darken in Fig. 6, a, it is evident that THI values also rise, with areas depicted in darker red indicating THI values surpassing the recommended threshold.

When dairy cattle are subjected in environments with high THI values, they can decrease dry matter consumption, rumination, and food bolus (Soriani et al., 2013). Consequently, these alterations directly affect milk production (Tao et al., 2018). When assessing conditions inducing heat stress in animals, it is crucial to analyze the duration and accumulation of heat load over successive days (Heinicke et al., 2018; Frigeri et al., 2023a).

To identify critical THI thresholds is valuable for decision-making regarding productivity and animal welfare, it should not be the sole determinant but rather complemented with behavioural, physiological, and regional considerations (Foroushani & Amon, 2022). The rise in temperature can also stem from metabolic processes, such as the generation of metabolic heat during rumination and food digestion in cows (Liu, 2019). Therefore, integrating THI with other factors becomes essential, given the variations among dairy cow breeds, age, milk production, geographic location of the barn, and housing types (Hoffmann et al., 2020).

Lack of mechanical ventilation may result in higher THI values, causing discomfort for animals (Mota et al., 2019). However, with the LVHS ventilation system, THI values ranging from 73 to 76 can be achieved under conditions similar to those in this study (Oliveira et al., 2019).

In Compost Barn type facilities, natural ventilation does not ensure comfortable conditions for the animals or adequate aeration for the bedding (Caldato et al., 2019). Therefore, it is necessary to utilize mechanical ventilation and regularly assess its effectiveness at two levels (animal and bedding), as it is not uniformly distributed (Oliveira et al., 2023).

For this survey, the values of V at a height of 0.25m from the bed (Fig. 6, b) showed large variations along the length of the installation, with a minimum of 0 m s^{-1} and a maximum of 3.3 m s^{-1}. The V values lower than 1 m s^{-1} were recorded mainly in the feeding area, which is a region with no direct mechanical ventilation, and low animal permanence. For Compost Barn type installations, it is common for air velocity to present high dispersion, due to sudden changes in magnitude and direction (Faria et al., 2008; Oliveira et al., 2023).

Insufficient ventilation results in increased RH and the accumulation of gases within facilities (Ding et al., 2016). Indeed, V will influence the intensity of gas dispersion and the time they remain inside the installations. This dispersion for CH_4 and CO_2 gases can be observed in Fig. 6c and Fig. 6, d, respectively.

The distribution of CH_4 (Fig. 6, c), at a height of 0.25m, shows a range of 24 meters (between coordinates 24 and 48 on the X axis) in which concentrations vary between 130 and 210 ppm. A single point recorded the maximum value of 253 ppm for CH_4 on the West side of the installation (indicated by dark red color). These values are above the limits for CH_4 concentration in milk production, which vary between 60 and 117 ppm (Jungbluth et al., 2001).

High values of CH_4 can cause discomfort to the animal, mainly reducing feed efficiency (Honan et al., 2022), if the scenario persists, the producer may consider adopting other strategies, such as reformulating the animal's diet (Schären et al., 2017; Wesemael et al., 2019; Ku-Vera et al., 2020; Bharathidhasan, 2022).

The heat retained inside the installation is responsible for altering the behaviour of the gases. In the case of CH_4 (lower density), it disperses quickly and is retained in the highest part of the installation (Damasceno, 2020). These concentrations must always be validated for each region due to factors that affect the production and emission of GHGs, including the type of facility for the animals, breed, consumption and composition of feed, local climate, among others (Huang & Guo, 2018).

According to Becciolini et al. (2022b), the methane electrochemical sensor used in this research yielded plausible yet lower values compared to other methane measurements using sampled air. Nevertheless, it is still possible to utilize this sensor to assess the variability of gas within the Compost Barn and the differences in regions with higher or lower concentrations of the methane.

Among the sources and strategies for reducing GHG emissions are: (1) storage of liquid and unprocessed waste, which is a more polluting source than dry waste, with processing capable of reducing these emissions (Aguirre-Villegas & Larson, 2017); (2) the animal's metabolism, in which case emissions are controlled by adding or replacing feed components (Hammond et al., 2016; Holtshausen et al., 2021; Baceninait et al., 2022). Research involving CH_4 emissions from livestock mainly considers emissions from eructation (Sorg, 2022), however, it is necessary to develop cost-effective technologies and methods for monitoring and systematizing emissions present in facilities, in order to establish other ways to mitigate GHG (Becciolini et al., 2022a; Becciolini et al., 2022b).

The CO_2 distribution (Fig. 6, d) indicates that concentrations in the largest areas vary from 380 to 500 ppm. This range falls below the limits found by Jungbluth et al. (2001) for dairy farming, which may vary between 970 and 1,480 ppm. Notably, a peak concentration of 713.6 ppm was recorded on the west side, within the feeder lane. According to Bewley et al. (2017), the concreted corridor retains approximately 25% to 30% of all manure and urine produced, which in some cases can result in elevated gas concentrations. The presence of CO_2 in the corridor may also be attributed to the animals' feeding behaviors, as they are metabolically active and tend to cluster together (Zou et al., 2020).

As it is a dense gas, CO_2 tends to concentrate in the lowest parts of the installation (Damasceno, 2020), which can be accentuated in the Compost Barn due to the decomposition of the material used for bedding. According to Ding et al. (2016), CO_2 emissions from waste increase considerably with increasing t_{db} and become more dispersed with increasing V on the surface.

In general, the production of polluting gases within the facility is affected by V, t_{db}, and RH, which strongly depend on constantly changing weather conditions (Hempel et al., 2016).

The use of geostatistics enabled the assessment of the spatial distribution of greenhouse gases within a Compost Barn during the evaluated period. The concentration of these gases can impact air quality and consequently the comfort and well-being of the animals, while also contributing to the emission of these gases into the atmosphere, which may contribute to global warming. Moreover, geostatistical analysis allows producers to identify areas with higher or lower concentrations of these gases, aiding in decision-making and the identification of management issues.

CONCLUSION

The semivariograms allowed us to characterize the instantaneous spatial variability of the greenhouse gases CH_4 and CO_2, as well as environmental variables such as THI and V at the height of the bed, inside the Compost Barn. For gases and the thermal index, the predominance of spatial dependence was strong, while for V the dependence was moderate.

Spatial maps were created to identify spatial variability based on kriging interpolation. The concentration of CH_4 at 0.25 m of bed height was more evident on the east side, except for a small region to the west of the installation. For CO_2, the highest values were on the west side of the installation. The analysis of greenhouse gas concentrations is crucial for mitigation actions and the development of an increasingly sustainable production system.

The V at 0.25 m bed height resulted in a very heterogeneous distribution, with a small region presenting values above 3.2 m s^{-1}. The non-uniform behavior of V indicates the possibility of promoting greater intensification of ventilation for unreached regions. The THI gradient showed elevations from west to east, following the direction of air circulation caused by the fans. The THI allows decisions to be made regarding the animal's thermal comfort and can be used in conjunction with observations of the animal's physical state.

Due to the various climatic variations in Brazil, this survey can be considered in other regions to better characterize the dispersion of gases in the Compost Barn system.

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