Carbon Dioxide Levels in a Cow Milking Parlor

Dimo Dimov[1], Toncho Penev[1], Ivaylo Marinov[2], Gergana Bachevska[1]

[1]Department of Ecology and Zoohygiene, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria
[2]Department of Animal Husbandry – Ruminant Animals and Animal Products Technologies, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria.

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Abstract. *The survey was conducted on a Bulgarian farm with 500 Holstein-friesian dairy cows housed in free-stall dairy operation. Measurements of carbon dioxide (CO_2) levels were taken in 2 x 8 "Herringbone" milking parlor. Monthly within a year, during the morning, midday and evening milkings, measurements were taken at the beginning, half-way through and at the end of the milking of the herd. Carbon dioxide levels were monitored with a Lutron MCH-383SDB (Lutron Electronic Enterprise Co., LTD., Taiwan). At the same time, the temperature-humidity index (THI) levels were recorded using the "Kestrel 5400" Weather Meter (Kestrel Instruments, USA). The highest average values of carbon dioxide in the air of the milking parlor were recorded in the winter season (756.67 ppm), and the lowest in the summer season (435.8 ppm). The highest recorded THI values were in the summer – 72.8, and the lowest in the autumn – 53.5. The highest CO_2 values were found at THI levels around 50, established in autumn and winter, because ventilation in the milking parlor was poor.*

Introduction

Ruminant livestock farming is responsible for 18% of greenhouse gas emissions in the EU (EFSA, 2009). As a greenhouse gas carbon dioxide plays an ambivalent role being essential for life on the planet and at the same time having negative effect on climate (Eldesouki et al., 2023). High concentrations of the gas have a negative effect on cows but also on people involved in farming. If animals are exposed to air concentration of carbon dioxide above 1% chronic intoxication, lower productivity and reduced resistance to disease can occur (Vtoryi et al., 2017). CO_2 concentration is affected by three factors, i.e. number of milkings, the type of ventilation system and local climatic conditions (Souza et al., 2024). Microclimate and ventilation are important factors that characterize air quality in farms (Mijid, 2013). Carbon dioxide is one of the key parameters of microclimate. Relative air humidity and concentration of harmful gases like carbon dioxide and ammonia could increase due to poor ventilation. According to Jovović et al. (2015), the carbon dioxide concentration is connected to the design of the barn, ventilation capacity and whether the number of the animals corresponds to their needs of a living space. Improving ventilation is beneficial in terms of animal health, welfare and productivity (Lovarelli, 2024). Carbon emissions in dairy farms are mainly associated with the cultivation and processing of feed, enteric fermentation of cows, the treatment of manure, and the energy consumption in dairy farms (Wang et al., 2024). The creation and provision of a suitable indoor environment especially for the summer season for dairy cows is getting more attention in recent years (Kic, 2022). Animals are milked in different types of milking parlors. Regardless of the type of the milking parlor, it is located in close proximity to livestock premises. It is necessary to determine the carbon dioxide levels inside a milking parlor, compare them with the outside concentrations and determine effectiveness of building isolation from the influence of temperature and humidity responsible for generation and accumulation of carbon dioxide. All this gave grounds for conducting the present study.

The study aimed to determine the concentration of carbon dioxide in a milking parlor, identify the factors influencing variations of the levels of concentration, and assess the possibility of a risk for the dairy cows' welfare.

Materials and methods

For the purpose of the study, the milking parlor of a dairy cattle farm for 500 Holstein-Friesian cows was selected. The type of milking parlor was 2 x 8 "Herringbone", no mechanical ventilation. The milking parlor had been installed 10 years prior to the study. Cows were milked three times during the day: at 5:00 a.m., at 12:00 a.m. and at 6:00 p.m. One milking of the herd lasted 2.5 hours.

Triplicate recording of carbon dioxide levels and THI were performed during each milking: at the beginning, half-way through and at the end of the milking. They were carried out during the morning, midday and evening milking at the level where the animals were standing in the milking parlor, from May 2018 to May 2019. Measurements of carbon dioxide and THI levels in the atmosphere were taken 10 meters away from the buildings. Carbon dioxide levels were determined by a "Lutron" MCH-383SDB (Lutron Electronic Enterprise Co., LTD., Taiwan) (Fig. 1).

Weather station "Kestrel 5400 (Kestrel Instruments,

Corresponding author: gergana.iotova@trakia-uni.bg

Fig. 1. Lutron MCH-383SDB

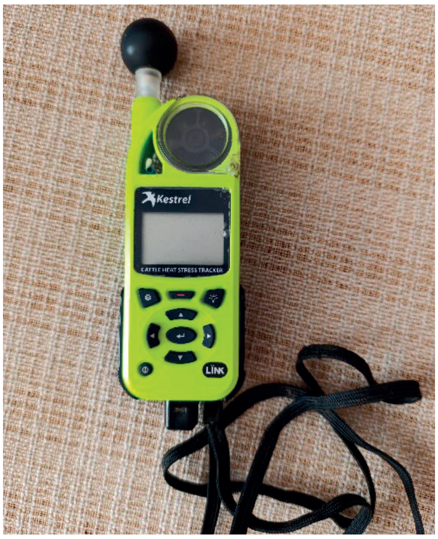

Fig. 2. Weather Meter "Kestrel 5400"

USA)" was used for direct measurement of the temperature-humidity index (Fig. 2).

THI values are in 6 classes determined by calculations: class 1 – ⩽ 50; class 2 – from 50 to 58; class 3 – from 58 to 68; class 4 – from 68 to 72; class 5 – from 72 to 74; and class 6 – ⩾ 74.

A basic statistical processing of data, determining mean values, errors and analysis of variance was performed with MS Excel along with corresponding modules of STATISTICA of StatSoft.

To assess the influence of the factors, the following model was used:

$$\boldsymbol{Yijklm = \mu + Si + Mj + Pk + THIl + eijklm}$$

Where ***Yijklm*** is the dependent variable (carbon dioxide); ***μ*** is the average for the model; ***Si*** is the effect of the reporting season; ***Mj*** is the effect of consecutive milking for the day; ***Pk*** is the effect of consecutive reporting for the milking; ***THIl*** is the effect of THI (class); and ***eijklm*** is the effect of uncontrolled factors (error).

The least squares of means by classes of the fixed factors were obtained by ANOVA to fit the model.

Results and discussion

Table 1 presents the average values for the reported CO_2 and THI levels inside the milking parlor and outdoors. Measurements of both indicators in the milking parlor were taken at the beginning of the milking, before production process, animals and people could affect them. The significance of the differences was calculated between the averages for each indicator outside and inside by season.

Average CO_2 values in the outdoor atmosphere were relatively low for all seasons. The lowest average values of CO_2 indoors were for the summer season – 196.3 ppm, and the highest for the winter season – 269.3 ppm.

The anthropogenic factor leads to a steady increase of atmospheric concentration of CO_2. From 280 ppm concentration of CO_2 in the 1800s, to 320 ppm in 1960, it has now reached 420 ppm, the highest level ever recorded (Oliveira, 2024).

The reported low levels of CO_2 in the area of the farm are due to the fact that it was located in an area with no industrial enterprises, it was less populated and therefore with less traffic. The use of solid fuels for heating in the area was a prerequisite for the reported higher values during cold seasons, especially winter.

The area had a milder climate and high temperatures during the warm months of the year. Seasonal average THI values confirm this. The highest values were recorded during summer – 75.8 and spring season – 70.3.

The values of the temperature-humidity index fall into classes related to different levels of heat stress. Various authors state that heat stress occurs when THI is from 68 to 74 (Herbut, 2018). Armstrong (1994) considers that when the index is below 71 cows are in the comfort zone, values ranging within 72–79 cause mild stress, within 80–89 they cause moderate stress, and when values are above 90, there is severe stress. According to Segnalini et al. (2013), 68 is the threshold value as values of THI between 68 and 72 are considered mild discomfort. Data shows that during summer days inside and outside the milking parlor, THI values that were recorded fall outside the comfort zone for dairy cows. Different studies suggest these values could be classified as moderate stress and uncomfortable conditions or even risky (Segnalini et al., 2013).

The average measured CO_2 values in the milking parlor at the beginning of milking are significantly higher than those outside, i.e., 2 to 3 times for the different seasons. Differences in average values for CO_2 inside and outside the building were significant for all seasons. This was not the case with THI values. The differences inside and outside the parlor were insignificant. Only for the summer season the difference was statistically significant ($P < 0.05$). This indicated a weak isolation of the milking parlor from the influence of external climatic conditions. The parlor was located next to the animal premise and there was air exchange between them. In addition, the parlor lacked mechanical ventilation and was only ventilated during the warm months when the curtains of semi-open barn were up. All this was a prerequisite for stagnant and low-quality air in the milking parlor at the very beginning of the milking of the animals.

Table 2 presents the results of the analysis of variance for the influence of the factors controlled in this study on CO_2 values in the milking parlor. Consecutive milking (morning, midday and evening) and consecutive reporting for the milking (start, middle and finishing) had no significant effect on CO_2 levels in the parlor. An effect of high statistical significance was reported for the season ($P < 0.001$), followed by THI values (in classes) ($P < 0.05$).

The proximity of the milking parlor to the animals' premise caused continuous air exchange between them. Curtains of the livestock premises were lowered in winter months and on certain days during transition seasons. Humidity of the air in the milking parlor increased, which led to higher values of carbon dioxide in the milking parlor. Jovović et al. (2015) studied 38 dairy cow buildings in the area of 10 municipalities in the region of Bosnia and Herzegovina and reported similar tendencies. Average values of carbon dioxide in their study were 871.57 ppm in winter, varying from 390 to 1690 ppm. During the summer season, ventilation was better because of the opening of windows and doors and, as a result, concentration of carbon dioxide in the cow premises was lower than in the winter. A study by Vtoryi et al. (2016) showed that the air temperature outside the buildings and the carbon dioxide content in the cowshed were inversely proportional.

Erbez et al. (2015) reported for carbon dioxide levels averaging 627.5 ppm (ranging from 390 to 890 ppm) in loose-housing buildings and 936.7 ppm (ranging from 390 to 1690 ppm) in tie-housing building. Jannat et al. (2025) found even lower carbon dioxide concentration averages of 612.44 ppm, ranging from 643.13 to 536.04 in a milking parlor of a dairy farm. Kaasik et al. (2013) found a clear seasonal variation: in summer, the concentration of CO_2 and relative humidity inside uninsulated loose-housing cattle buildings were lower than in winter, with an overall mean indoor CO_2 concentration of 553 ppm.

Ordinance 44 (MAFWE, 2006) stated that CO_2 concentration could not exceed 0.3% or 3000 ppm. Both values obtained in our study, i.e., the average and the maximum deviations, were below the limit value. The Ordinance concerns livestock premises, and we perceive the milking parlor as such, even though the animals do not spend the whole day there, but the regulation lacks specifics about milking parlors.

Fig. 3 presents the seasonal variation of carbon dioxide values during the different milkings of the day – morning, midday and evening. During the three milkings for the day, the lowest average CO_2 values

Table 1. Carbon dioxide and THI average values inside the milking parlor and outside in the farm area for different seasons

Season	Number n	CO_2 inside, ppm	CO_2 outside, ppm	THI inside, value	THI outside, value
		x ± SE	x ± SE	x ± SE	x ± SE
Summer	9	435.8 ± 50.99***	196.3 ± 7.47***	72.8 ± 0.86*	75.8 ± 0.87*
Autumn	6	592.0 ± 104.76**	235.8 ± 18.07**	53.5 ± 1.79-	51.6 ± 2.46-
Winter	3	756.67 ± 23.14***	269.3 ± 12.14***	54.4 ± 0.77-	54.4 ± 0.38-
Spring	11	682.18 ± 53.19***	220.18 ± 10.89***	68.6 ± 2.38-	70.3 ± 2.99-

*** – significance at $P < 0.001$; ** – significance at $P < 0.01$; * – significance at $P < 0.05$; - n.s.

Table 2. Analysis of variance for influence of controlled factors on CO_2 values in the milking parlor

Sources of variation	CO_2 values inside the milking parlor		
	(n – 1)	MS	F *P*
Total for the model	12	119 318	3.69***
Reporting season	3	225 681	6.98***
Consecutive milking for the day	2	919	0.03-
Consecutive reporting for the milking	2	68 441	2.12-
THI	5	93 618	2.90*
Error	74	32 318	

*** – significance at $P < 0.001$; ** – significance at $P < 0.01$; * – significance at $P < 0.05$; - n.s.
MS = mean square, F = value of the factor, *P* = level of significance; "-" lack of significance

were the in the summer season ranging from 432 to 516 ppm, with a maximum deviation of 813 ppm in the evening milking. In winter, the highest average values for CO_2 compared with the other seasons were from 725 to 789 ppm, reaching maximum values above 800 ppm.

Animals coming in the milking parlor result in a rise of carbon dioxide levels. During milking, perspiration and frequency of breathing increase thus leading to indoor air temperature and relative air humidity increase. With each milking session of a technological group of animals, air quality deteriorates (Herbut et al., 2012).

A significant effect of THI values on those of CO_2 in the milking parlor was reported. Fig. 4 presents LS mean values for CO_2 levels depending on THI values (in classes).

The highest CO_2 values (914.6 ppm) were reported when THI values were lowest – below 50. Medium high values of 591.2 ppm to 605.5 ppm were reported at optimal THI values of 50 to 72. Values of THI above 72 classified as risky were accompanied with an increase in CO_2 values. CO_2 reached 715 ppm when THI was above 74. For both the low and the high THI values, the crucial factor for reducing the level of carbon dioxide in the milking parlor was the ventilation of the premise. During the cold months, the curtains of the barn were down and there was no ventilation at all, resulting in the retention of all harmful gases in the human and animal area.

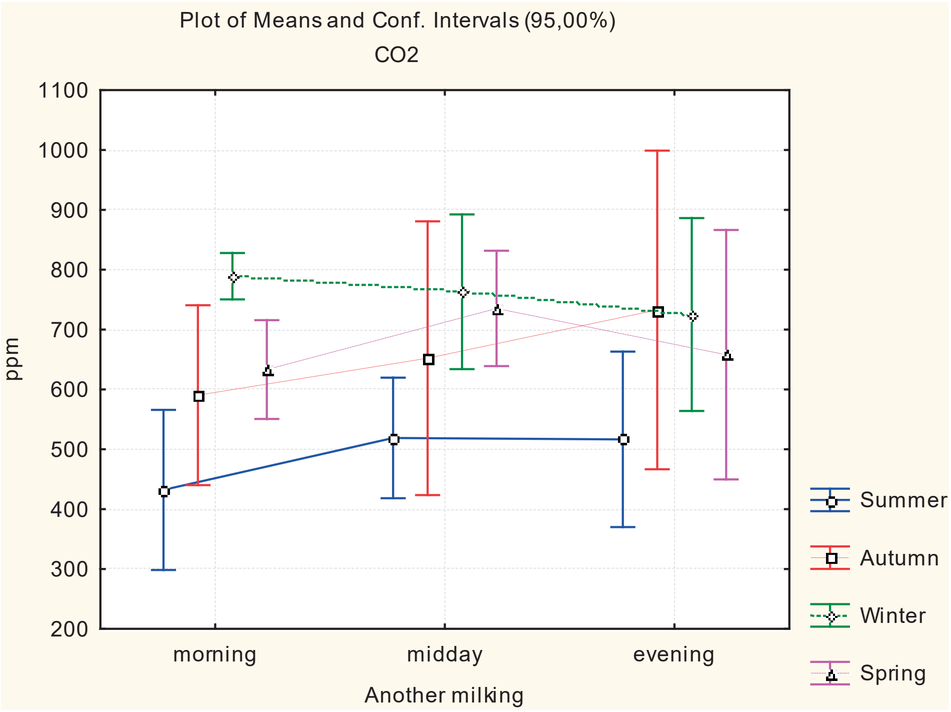

Fig. 3. Seasonal average values and raging of carbon dioxide during the different milkings for the day

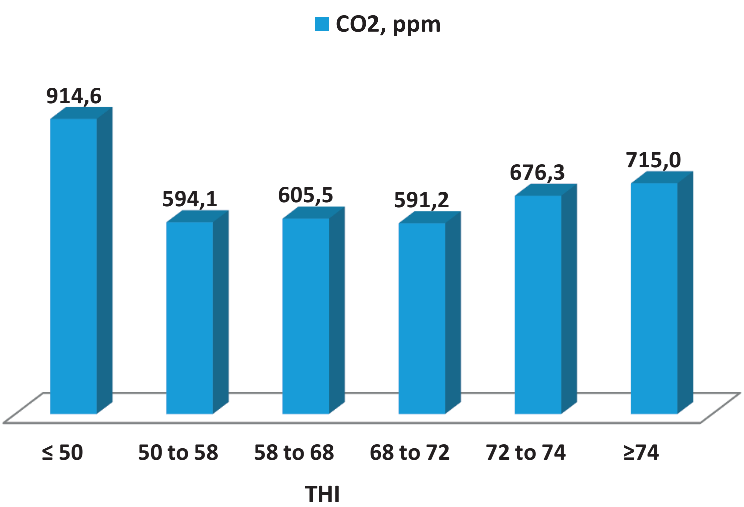

Fig. 4. LS mean values for CO_2 levels depending on THI values (in classes)

During the warm months, although the curtains were raised, outside conditions and inside conditions were the same, which resulted in higher THI values and higher CO_2 levels due to an increase in the respiration rate. Because the livestock facility was not separated from the milking parlor by doors or other barriers, air from the livestock building entered the milking parlor unhindered, which undoubtedly affects CO_2 values.

In a study by Dimov et al. (2019) of three cattle farms over different technological zones in the livestock premises, carbon dioxide values were lowest when the temperature-humidity index was within the range from 58 to 74 and air velocity from 0.6 to 1.0 m/s. High humidity and low temperatures were prerequisites for CO_2 retention in the low air layers of the premise.

Jeelani et al. (2019) suggest little changes for the animal at THI 72, but major physiological changes happen when THI reaches 74. At THI range within 74–79, animals maintain homeostasis, but it is perturbed at THI 80. Overall recalibration of THI is needed to make accurate assessment of heat stress depending on the climatic region. Heat stress in cattle accelerates respiration, pulse rate, and metabolism. Other indicators of heat stress are a decrease in feed intake and an increase in water intake, increased rectal temperature, an increase in water loss through evaporation, and a change in the concentration of hormones in the blood (Koubková et al., 2002)., The light increase in carbon dioxide levels in our study was due to the increased respiratory rate corresponding with THI values above 72. Although the cows stay in the milking parlor for a short time, the combination of high THI and CO_2 values could have a stressful effect on the animals.

Conclusion

The average carbon dioxide air concentration in the milking parlor ranged from 435 to 756 ppm, with the highest values registered in the winter season and the lowest in the summer. The trend for carbon dioxide values by seasons outside the parlor was similar to the reported inside it, but the milking parlor values were 2 to 3 times higher, ranging from 196.3 to 269.3 ppm again lowest in summer and highest in winter. The average values of THI of the air of the milking parlor ranged from 53.5 to 72.8, with the highest values recorded in the summer season and the lowest in the autumn. Outside the milking parlor, the reported THI values ranged from 51.6 to 75.8, again highest in summer and lowest in autumn. Highest values of carbon dioxide were recorded when THI was near 50 or as high as 74 and above. As a preventive measure, a precise regulation of the ventilation system in a milking parlor is necessary, even though the values of the study are in the norm according to the current legislation.

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