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Carbon dioxide levels in the working area of a cow milking parlor

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Abstract

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The study was conducted on a dairy cattle farm with capacity of 500 dairy cows in Bulgaria. The animals were reared under the conditions of free-stall housing system and milked in double-8 "Herringbone" type milking parlor. Carbon dioxide levels were reported three times during each milking (at the beginning, in the middle and at the end of the milking), with the measurements repeated during the morning, noon and evening milking, every month for a year. Carbon dioxide levels in the milkers working area were measured using a Lutron MCH-383SDB. The highest average values of carbon dioxide in the air inside the milking parlor were registered during the winter season (789.3 ppm) and partly during the autumn and spring seasons, which are transitional seasons, with the maximum reported value being 1451.0 ppm. The lowest values of carbon dioxide in the milking parlor were reported during the summer season – 432.3 ppm. The trend was similar to the reported levels of carbon dioxide outside the premises, but the values in the milking parlor were 2 to 3 times higher. The reported values of carbon dioxide in the working area of milking parlor gradually increased from the beginning to the end of the relevant milking.

Keywords: carbon dioxide; dairy cows; milking parlor; working environment

Introduction

According to EFSA (2009), 18% of EU greenhouse gas emissions are due to ruminant livestock farming. One of these gases is carbon dioxide. Its high concentration has a negative effect on both animals and farmers. Carbon dioxide is one of the important components of the microclimate. It has no color, does not burn, is heavier than air and therefore at low air movement in the premises has a high concentration and increases due to water vapor in the air (Pchjolkin, 1977). Poor ventilation can increase the relative humidity and concentration of harmful gases such as carbon dioxide and ammonia. The concentration of carbon dioxide depends to a large extent on the type of building, the ventilation system and the density of the animals (Jovović et al., 2015). The sources of carbon dioxide (CO_2) in buildings for cows are: animal respiration, feed emissions, manure and in insignificant amounts of emissions of technological energy (fuels, electricity) (Schiefler, 2013).

The presence of carbon dioxide in large quantities is considered as an indicator of poor microclimatic conditions in livestock premises (Vučemilo & Tofant, 2009). Very often, when people are exposed to high levels of carbon dioxide, they feel psychologically tired, unable to cope with the tasks assigned to them, especially if they are related to mental activity (Haverinen-Shaughnessy et al., 2011; Mendell et al., 2013). Kajtár & Herczeg (2012) conducted an experimental study by closing 10 people in a chamber and increasing carbon dioxide levels to 3000 ppm in 2-3 hours. The authors found an increase in diastolic blood pressure, stress and excitement.

The aim of the study was to determine the levels of carbon dioxide in the working area of the milking parlor and to determine whether there was a danger to the milkers health.

Material and Methods

The study was conducted on a cattle farm with 500 dairy cows in Bulgaria. The milking parlor was double-8 "Herringbone" type. The milking installation has been in operation for 10 years. This type of milking parlor is widely used in Bulgaria. There was no mechanical ventilation inside it. In the farm subject of the study were housed Holstein-Friesian cows. There were four male milkers on the farm were, aged 40 to 55 years, milking by two per shift. The duration of one milking was within 2.5 hours, three times a day. Milking in the morning started at 5:00 h, at noon at 12:00 h and in the evening at 18:00 h.

The carbon dioxide levels were reported three times during each milking (at the beginning, in the middle and at the end of the milking), as the measurements were repeated during the morning, noon and evening milking in the working area of the milkers. The reporting was performed every month for one calendar year.

Atmospheric carbon dioxide levels were also reported in the farm area at a distance of 10 m outside the buildings under study. The carbon dioxide levels were reported using a Lutron MCH-383SDB device (Figure 1).

Fig. 1. Lutron MCH-383SDB

For a basic statistical processing of the data a package MS Excel was used, and for determining the average values, errors and analysis of variance, the corresponding modules of STATISTICA of StatSoft.

Results and Discussion

Table 1 presents average values and standard deviations of the level of carbon dioxide in the working area of the milking parlor by sequential milking and by season of reporting. The highest average values of carbon dioxide in the air of the milking parlor were registered during the winter season (789.3 ppm) and partly during the autumn and spring seasons, which are transitional seasons. The lowest values of carbon dioxide in the milking parlor were reported during the summer season – 432.3 ppm. The low levels of dioxide during the summer months were most likely due to the fact that the curtains of the livestock premises were not lowered and there was although weak movement of air, which was enough to remove part of the carbon dioxide in the indoor air.

The milking parlor was in close proximity to the animal's premises and there was a constant exchange of air with them. During the winter months and on certain days of the transition seasons, the curtains of the livestock premises were lowered, in addition, the humidity in the parlor was higher, which was a prerequisite a higher values of carbon dioxide in the milking parlor to be reported. Dimov et al. (2019) found that in cow buildings in the summer the lowest values of carbon dioxide were reported due to increased ventilation, and in the winter the highest.

Also considerable variations were reported in the carbon dioxide values in the working area of the milking parlor, as the maximum reported values were respectively 1190.0 and

Table 1. Average values and standard deviation of the carbon dioxide level in the milking parlor by sequential milking and by season of reporting

Milking	Number n	Carbon dioxide, ppm			
		X ± Se	SD	Min	Max
Summer					
Morning	9	432.3±57.99	173.98	276.0	691.0
Noon	9	519.1±43.65	130.95	390.0	774.0
Evening	9	516.8±63.55	190.64	314.0	813.0
Autumn					
Morning	6	590.5±58.46	143.20	428.0	775.0
Noon	6	652.3±88.93	217.83	400.0	923.0
Evening	6	733.0±103.52	253.56	289.0	946.0
Winter					
Morning	3	789.3±8.99	15.57	773.0	804.0
Noon	3	763.3±30.02	52.00	711.0	815.0
Evening	3	725.3±37.44	64.84	657.0	786.0
Spring					
Morning	9	633.4±35.79	107.36	534.0	860.0
Noon	12	735.5±43.76	151.57	622.0	1190.0
Evening	12	658.2±94.65	327.89	198.0	1451.0

1451.0 ppm in the spring season and over 900 ppm in the autumn season.

The established values of both the averages and the maximum deviations were below the limit value determined by Ordinance 44 (MAF, 2006), respectively up to 0.3% or 3000 ppm. A level of 5000 ppm is used as the occupational exposure limit for carbon dioxide (CO2) (ACGIH, 2011), so levels of 5000 ppm and higher are expected to lead to toxic effects if exposure at such a level is longer of 8 hours and carbon dioxide is the dominant component of the exposure. The values reported by us were well below this limit value. At levels close to 5000 ppm and lower, headache, eye fatigue, shortness of breath, etc. are observed, and the symptoms begin to decrease at carbon dioxide values below 800 ppm (Tsai et al., 2012; Norbäck et al., 2013).

According to Ogden (2019), exposure to carbon dioxide (CO_2) indoors poses direct risks to human health at lower levels than previously thought, causing health problems such as inflammation, reduced cognitive performance and kidney and bone problems. It has been found that these health problems can be caused by exposure to carbon dioxide levels of up to 1000 ppm – a far lower limit than the level of 3000 ppm, which is widely accepted.

Azuma et al. (2018) also believe that the effects of low level carbon dioxide exposure on human health need to be reconsidered in the light of the current trend of increasing carbon dioxide concentrations in the atmosphere. A human study reports that exposure to carbon dioxide at levels of 1000 ppm for a short time, causes significant changes in the amplitude of respiratory movements, peripheral blood flow increases and leads to changes in the functional state of the cerebral cortex. The concentration of carbon dioxide (CO_2) in the range of 674 – 1450 ppm is significantly associated with headaches and this relationship is independent of other related internal environmental factors, including temperature, relative humidity (Norbäck & Nordström, 2008). According to Azuma et al. (2018) recent studies show clearly linear physiological changes in the circulatory, cardiovascular systems, including increased levels of carbon dioxide (CO_2) in the blood, increased blood pressure, increased heart rate, increased peripheral blood circulation, and increased sympathetic stimulation at exposure to carbon dioxide in the range of 500 to 5000 ppm (Zhang et al., 2017).

In the light of these new studies on the effect of low concentrations carbon dioxide on the health of people working in such an environment, it is seen that the reported average values and variation of carbon dioxide in the milking parlor were in almost all seasons and milkings above 500 ppm, reaching levels above 1000 ppm, which could lead to health problems in milkers.

Figure 2 presents the variation of the values of carbon dioxide during milking – in the beginning, middle and end of milking, by seasons. A regular increase in carbon dioxide levels was reported from the beginning to the end of milking. The largest increase in the level of carbon dioxide (CO_2) from the beginning to the end of milking was found during the spring and autumn seasons – by more than 140 ppm. In winter, the increase was lower, but the level did remain highest during the whole milking – over 700 ppm. The increase in carbon dioxide levels in the milking parlor during milking is due to the effect of the animals that passing for milking. Cows produce large amounts of heat, water vapor and carbon dioxide. Sweat production and respiration rate increase during milking, leading to an increase in internal temperature, relative humidity and air quality in the milking parlor. If the milking parlor is not equipped with an efficient ventilation system, the conditions worsen with the milking of the next technological cow groups (Herbut et al., 2012).

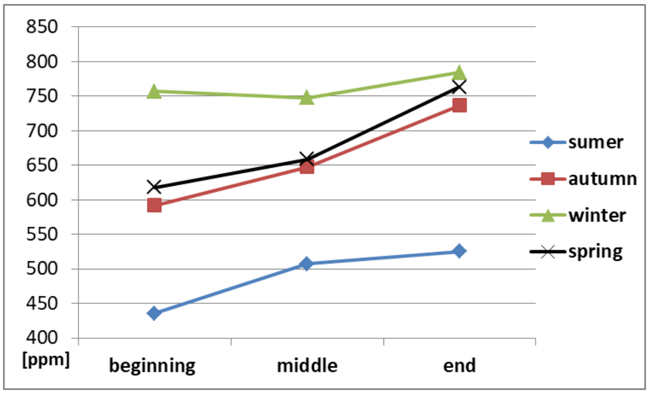

Fig. 2. Changes in the values of carbon dioxide during the milking process by seasons

In large farms, milking takes place in several technological groups, which leads to a gradual deterioration of microclimatic conditions in the milking parlor as the next groups for milking pass through. Also, the comfort of the milker's workplace decreases during milking. The milking parlor under study was with capacity for servicing 500 cows, but for larger farms and respectively larger number of technological groups and capacity of the parlor, the levels of carbon dioxide would increase more than the reported values.

Table 2 presents average values and standard deviation of the level of carbon dioxide outside the milking parlor by sequential milking and by season of reporting. The highest average values of carbon dioxide in the air outside the milking parlor were registered in the winter season (285.5 ppm) and partly in the autumn season (280.5 ppm). The lowest values

Table 2. Average values and standard deviation of the carbon dioxide level outside the milking parlor by sequential milking and by season of reporting

Milking	Number n	Carbon dioxide, ppm			
		X ± Se	SD	Min	Max
Summer					
Morning	3	206.3±18.37	31.81	186.0	243.0
Noon	3	196.33±1.20	2.08	194.0	198.0
Evening	3	191.67±16.05	27.79	160.0	212.0
Autumn					
Morning	2	224.0±16	22.63	208.0	240.0
Noon	2	280.0±63	89.1	217.0	343.0
Evening	2	215.5±54.5	77.07	161.0	270.0
Winter					
Morning	2	285.5±5.5	7.77	280.0	291.0
Noon	2	254.5±4.5	6.36	250.0	259.0
Evening	2	264.0±4.0	5.66	260.0	268.0
Spring					
Morning	3	238.67±18.44	31.94	215.0	275.0
Noon	4	226.75±18.59	37.18	186.0	276.0
Evening	4	233.75±7.41	14.82	213.0	247.0

of carbon dioxide outside the milking parlor were reported during the summer season – 191.67 ppm.

The higher values of carbon dioxide outside the milking parlor during the winter season were probably due to the fact that the farm was located near a settlement (village), where solid fuel (wood and coal) was most often used for heating. At combustion of these materials considerable amounts of carbon dioxide were emitted into the air. Foggy weather in winter also helped to increase the levels of carbon dioxide. The average daily values of carbon dioxide outside the milking parlor in the area of the farm were within the limits of the average reported for atmospheric air. For all seasons, the average daily values ranged from 191.67 to 285.5 ppm. The reported levels of carbon dioxide in the area of the studied farm are much lower than those reported by a number of authors globally. The farm is located away from large settlements (cities), industrial sites and highways and this was the reason for the relatively low levels of carbon dioxide in the air of the region. Azuma et al. (2018) showed that outdoor carbon dioxide concentrations were approximately 380 ppm, although in urban areas they have reached 500 ppm, due to increased anthropogenic sources. Lindsey (2017) pointed that in 2013 the average values of global atmospheric carbon dioxide exceeded 400 ppm, and in 2016 it was 402.9 ppm.

According to the World Meteorological Organization, the global average concentration of carbon dioxide in the atmosphere has reached a symbolic and important stage of 400 ppm for the first time in 2015 (WMO, 2016) and increased to 403.3 ppm in 2016 (WMO, 2017). The average annual absolute increase over the last 10 years was 2.2 ppm per year (WMO, 2017).

Figure 3 presents the average values for carbon dioxide reported inside and outside the milking parlor by seasons. The average values of CO_2 inside the parlor were 2 to 3 times higher than those outside. The differences were statistically significant for all seasons (P<0.001).

The reported differences showed a deterioration of the air quality in the working environment of the milking parlor compared to the atmospheric conditions and indicate that the presence of ventilation would improve the microclimatic working conditions.

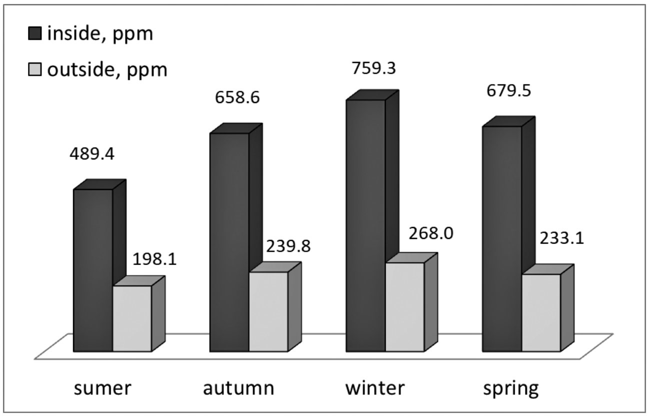

Fig. 3. Average values for carbon dioxide reported inside and outside the milking parlor by seasons

According to Lowitz (2015), elevated carbon dioxide levels of 600 – 700 ppm above the outdoor levels require a special focus on ventilation and emission sources. Although many existing global standards set a maximum daily average exposure of up to 5000 ppm, researches show that cognitive impairment and perception of poor air quality begin at 1000 ppm (absolute) or 600-700 ppm (differential) above the outside levels.

Conclusion

Average values of carbon dioxide in the air of the working area of the milking parlor fluctuated from 432.3 to 789.3 ppm, with the highest values reported in the winter season and the lowest in the summer. The maximum reported value was 1451.0 ppm. The trend by seasons was similar to the reported levels of carbon dioxide outside the premises, but the values inside the milking parlor were 2 to 3 times higher. The reported values of carbon dioxide in the working environment of the milking parlor gradually increase from the beginning to the end of the respective milking. The largest was the increase in the level of carbon dioxide from the beginning to the end of milking during the spring and autumn seasons – by more than 140 ppm. In winter the increase was smaller, but the level remained the highest, during the whole milking – over 700 ppm. It is necessary to refine the ventilation system in the milking parlor, although the reported values do not exceed the current norms, but according to new studies, the reported levels (above 500 ppm) lead to faintness and dizziness due to the longer period of exposure of milkers in the milking parlor, and hence to the efficiency of the work they do.

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