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Temperature-humidity working conditions in a milking parlor for cows

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Abstract

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The study was conducted in the milking parlour of a dairy cattle farm with a capacity of 500 Holstein-Friesian cows. The milking parlor was double-8 "Herringbone" type. There were no windows in the premises, and the roof structure was constructed of glass. The temperature, air humidity and Temperature-humidity index (THI) 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, midday and evening milking. The highest average air temperatures in the working area of the milking parlor were reached during the summer season for midday milking 27.1°C, and the lowest for the autumn season for evening milking 10.3^{0}C. The highest average value of the relative humidity – 89.2% in the milking parlor was reached in the winter season for midday milking, and the lowest in the spring season – 55.7%. Significant differences in the values of these indicators outside and inside the milking parlor were not reported. The values of the air temperature inside the milking parlor were significantly higher than the permissible levels for working environment in the spring-summer season (by 5 ⁻ 6°C) and lower in the autumn-winter season (by 4 to 6°C). The lowest values of THI in the milking parlor were reached in the autumn during evening milking – 51.4. The highest values for this indicator were reached during the summer season for midday milking – 75.6. The THI values for most of the year were also above the recommended standards of comfort at workplace. The values reported showed that for 4 – 5 months of the year the milkers were exposed to unfavorable temperature-humidity working conditions.

Keywords: milkers; milking parlor; temperature; humidity; THI

Introduction

Over the last decade, average annual temperatures are becoming higher worldwide and ultimately affect not only life but also the work environment in many areas of human activity (Ricco et al., 2020). One of the most affected by climate change activity is agriculture. In recent years, studies related to high ambient temperatures and increased risk of occupational injuries are increased (Bonafede et al., 2016; McInnes et al., 2017), especially in conditions characterized by a combination of exposure to workplace environment with heat sources and internally generated heat through physical activity associated with strenuous muscular activity (Kjellstrom et al., 2009; Ricco, 2018). According to Hajat et al. (2010) one of the most direct health effects resulting from climate change is expected to be the increased mortality and morbidity rates associated with exposure to high environmental temperatures.

In most countries, agriculture is recognized as one of the most widespread and dangerous activities for humans, accompanied by multiple musculoskeletal disorders (Fathallah, 2010; Niu, 2010). As part of the agricultural sector, a

dairy cattle farming is associated with heavy manual labor, which over time causes a number of diseases in workers, most often to the musculoskeletal system, but also to the respiratory system and hearing, especially in workers with the longest professional experience.

A number of studies have focused on increasing the welfare of dairy cows, challenged by improving the profitability of cattle breeding as an agricultural sector (Herbut et al., 2015). Following the new recommendations, farmers are modernizing existing farms to improve animal welfare (Bieda & Herbut, 2007), but the new conditions do not always comply with the requirements of workers working on these farms. None of the components determining the working environment in dairy cattle farms should be underestimated.

The risks to workers in dairy cattle farming are multicomponent and highly variable. On the one hand, the work is with large animals compared to other farm animals, on the other hand, requires knowledge of the nature of work (knowing the cows behavior, knowing of the presumptive risks in their service, requirements for quality and hygiene indicators of the milk produced). One of the activities associated with many risks of injuries and disabilities in dairy cattle farming is the cows milking. The transition to milking in milking parlors has led to improvements in the working conditions of the milkers (Nevala-Puranen et al., 1996). Although working conditions have changed in modern milking parlors, workers in them still experience work-related pain and have more accidents than other occupations (Pinzke, 2016). Jakob & Rosecrance (2018) show that occupational challenges, such as uncomfortable working postures, repetitive activities, prolonged or unfavorable working hours, cold or high temperatures and wet work environment, heavy workload do not attract many people, especially younger ones, to occupy this profession.

Temperature, humidity, ventilation and lighting are the main factors determining the comfort of the workplace. Deviations from satisfactory working conditions can reduce efficiency and have detrimental effects on workers' health. In the Bulgarian scientific literature there are no studies related to working conditions both in milking parlors and in cattle breeding in general, and the effects in workers (Dimov et al., 2020). Most of the milking parlors both in Bulgaria and in a number of other countries were constructed more than 10 years ago. Their orientation, level of insulation and cooling capacity are not consistent with the ongoing climate change and the new requirements for the working environment (Herbut et al., 2012; Herbut et al., 2015).

The goal of the study was to determine the values of temperature, humidity and THI in the working environment of workers in milking parlor during the individual milkings for the day and by seasons, and to determine whether the conditions correspond to the normatively determined permissible values for the working environment with a view a healthy and safe working conditions on cattle farms to be provided.

Material and Methods

The study was conducted in the milking parlor of a dairy cattle farm with a capacity of 500 Holstein-Friesian cows in Bulgaria. The milking installation was a "Herringbone" type with 2x8 units. The milking parlour was without windows and the roof structure was made of glass. The lighting in the milking parlour was luminescent. The milking installation has been exploited for 10 years. This type of parlour is widespread in Bulgaria, as it does not require much space and is relatively easy to modify.

There were four milkers on an employment contract on the farm, milking by two in shift. All milkers on the farm were men between the ages of 40 and 55. The duration of one milking was within 2.5 hours and it was performed three times a day. The start of milking was as follows: in the morning – 5:00 h, midday – 12:00 h and in the evening – 18:00 h. The temperature, humidity and THI were reported three times during each milking (at the beginning, in the middle and at the end of milking), and the measurements were repeated during the morning, midday and evening milking. The measurements were carried out in the milkers work area every month for one calendar year. The same indicators were reported in the area of the farm at a distance of 10 m outside the buildings subject to the study.

The levels of temperature and humidity in the milking parlor were recorded using a Lutron MCH-383SDB device (Figure 1). The THI was reported directly with the meteorological station "Kestrel" (Figure 2).

Fig. 1. Lutron MCH-383SDB

Fig. 2. Weather station "Kestrel"

The MS Excel package was used for basic statistical data processing, and the corresponding StatSoft STATISTICA modules (Copyright 1990-1995 Microsoft Corp.) were used to obtain the mean values, errors and variance analysis.

Results and Discussion

The farm falls into a climatic area characterized by a transitional continental climate. This climatic region covers the entire Upper Thracian lowland, the low Trans-Balkan valleys, the northern part of the Tundzha hilly and low mountain area and the Eastern Stara Planina. The average January temperature is from -1.5 to + 1°C, the average July temperature is from 22 – 24°C, and the maximum summer temperatures reach 40°C (Alexandrov, 2006). In recent years, there has been an increase in average temperatures, especially during the summer. Such data for the region of Southern Bulgaria was also indicated and by Dimov et al. (2017). The reason for choosing this particular farm was the assumption that summer temperatures will be a problem for workers.

In Table 1 are presented average values and standard deviation of the air temperature in the milking parlor by milking sequence and season of reporting. The highest average temperatures were reached during the summer season for midday milking 27.1°C, and the lowest for the autumn season for evening milking 10.3°C. The maximum temperatures reached 31.4°C during the midday milking, and the minimum ones fall to 7.9°C during the evening milking in the autumn.

Similar data on the air temperature in the milking parlor showed Herbut et al. (2015). The authors note that the increase in inside temperature from morning milking to midday milking coincides with the changing exposure to sunlight of the building and the increase was about 4-5°C. During the afternoon milking, the temperatures were also higher, reaching approximately 33°C. The same trend was observed in the milking parlor we studied. The average temperatures in the parlor were increased from 22.9°C during the morning milking to 27.1°C during midday milking in the summer and from 19.5°C to 24.5°C in the spring, respectively. According to a number of researchers, milking as a human activity is classified as hard physical labor (Lundqvist et al., 1997; Stal et al., 2000). According to the ordinance in force in the country, concerning the limit values of temperature during hard physical work for the cold period the norm is 16 – 18°C, and for the warm period of the year the norm is 18 – 21°C (Ordinance № RD-07-3 /18.07.2014). The average values found in this study were outside these norms for both temperature periods. For the cold period (autumn and winter) they were 4 to 6°C lower during the various milkings for the day, and during the warm period (summer and spring) they were 5 – 6°C higher than the indicated norms.

Table 1. Average values and variation of the air temperature in the milking parlor by milking sequence and reporting season

Milking sequence	Number n	Temperature, °C			
		X ± Se	SD	Min	Max
Summer					
Morning	9	22.9±0.21	0.64	22	23.8
Midday	9	27.1±0.69	2.07	25	31.4
Evening	9	25.8±0.21	0.80	24.4	26.7
Autumn					
Morning	6	12.4±0.66	1.60	10	14.4
Midday	6	11.5±1.04	2.56	8.8	14.3
Evening	6	10.3±0.92	2.25	7.9	12.4
Winter					
Morning	3	12.1±0.54	0.93	11.1	12.9
Midday	3	13.4±0.23	0.40	13	13.8
Evening	3	13.2±0.43	0.75	12.4	13.9
Spring					
Morning	9	19.5±1.19	3.58	14.5	23.3
Midday	12	24.5±1.59	5.52	15.2	29.5
Evening	12	21.3±1.68	5.82	11.3	26.5

The average values of the temperature inside the milking parlor for winter and summer reported in the present study do not meet even the norms indicated in the ordinance for light physical work, which the milking is not, for sure. The norms for such work are 20 – 23°C for the cold period and 22 – 25°C for the warm period (Ordinance № RD-07-3

/18.07.2014). During the summer season there was a maximum measured temperature of above 30°C reached during midday milking. This contradicts Art. 8 of the same ordinance, which sets a maximum limit value of air temperature at permanent workplaces (such workplaces are where the employee performs more than half of the statutory working hours) not higher than 26°C for heavy physical work. Exceeding these temperatures poses a potential danger to the workers. Microclimatic and light conditions are very important because they are often at the root of occupational diseases (Frazzi & Lodigiani, 1996). High ambient temperatures cause human thermal discomfort (Yousif & Tahir, 2013).

There are a number of studies on the relationship between intensive and prolonged occupational exposure to heat and the effect on workers' health of dehydration and spasms, increased fatigue, reduced productivity and increased risk of accidents (Kjellstrom & Crower 2011; Bonafede et al., 2016). Occupational exposure to low temperatures can increase cardiovascular and respiratory risks, musculoskeletal and dermatological disorders, and can cause hypothermia-related injuries (Mäkinen & Hassi, 2009). Low temperatures also lead to an increase in the degree of fatigue, as the body uses energy to warm up. There is also an increased risk of accidents due to numbness of the fingers. The too high temperature in the workplace can also lead to feeling of tiredness and less vigour, cause heat (muscle) cramps and put extra strain on the heart and lungs. Fatigue and loss of concentration, in turn, can lead to an increased risk of accidents (Sheng et al., 2018). While these problems are mainly caused by extreme temperatures (hot or cold), less severe but undesirable workplace temperatures can cause discomfort, loss of concentration, irritability, fatigue, and more.

Given that the work of milkers is related to the quality of production (milk), working in conditions outside the comfort can lead to insufficient diligence and attention in the various activities related to udder hygiene and health control.

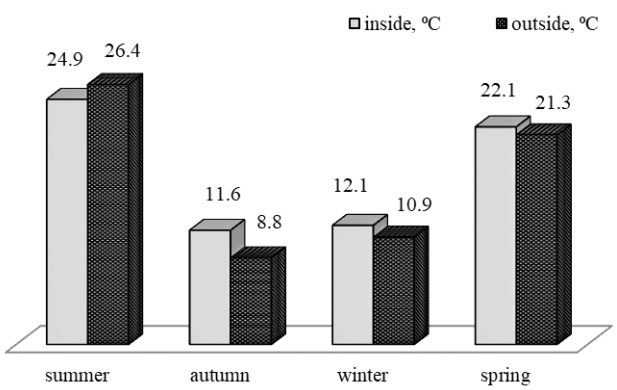

Fig. 3. Mean values for air temperature in the milking parlor and outside it in the open air by seasons

In Figure 3 are presented the average values of the air temperature in the milking parlor and outside it in the open air in the area of the farm by season of reporting.

In order to make a comparison between the two temperatures, as indoor temperature the first reported temperature of each milking was taken, which have not yet been influenced by the animals and the processes taking place in the milking parlor. The aim is to determine the insulation properties of the milking parlor, so as to provide better microclimatic conditions regardless of the external climatic conditions in the farm area. It is clear from the data that when comparing the reported outside and inside temperatures, no significant differences were found. This showed that the milking parlor did not have almost any insulating properties and was not able to provide a comfortable microclimate for work. The reported differences were about 2 degrees, and during the summer months the temperature was lower inside the milking parlor, and during the rest of the months it was higher than outside.

Herbut et al. (2012) showed that high air temperatures in the milking parlor were due to prolonged exposure of the roof to sun, which makes it impossible to reduce indoor temperatures without additional cooling (ventilation, etc.). The authors found that in July, before the evening milking, the air temperature inside the milking parlor was lower than the outside temperature by only 0.5 – 1.5°C.

On the Table 2 are presented the average values and standard deviation of the relative humidity in the milking parlor by milking sequence and season of reporting. The highest average value of the relative humidity in the milking parlor was reached in the winter season during midday milking – 89.2%, and the lowest in the spring season – 55.7%. The optimal limit values for the relative humidity in the working premises are in the range of 40 to 60% (Ordinance № RD-07-3 /18.07.2014), the same values were indicated by Kunc et al. (2007). The most favorable season in terms of relative humidity was the summer, where the average values of this indicator slightly exceed 60%, and the most unfavorable season was winter, when values close to 90% were reached. Long-term exposure to relative humidity above 85% adversely affects the human body and the equipment used. High relative humidity is the cause of damage to building structures, whether metal or wood (Papez & Kic, 2013; Zejdova et al., 2014). No minimum limit values below 40% relative humidity were observed for the entire study period, however, the maximum permissible values ware significantly exceeded, especially for the autumn and winter seasons.

According to the current regulation, relative humidity of up to 75% is allowed for permanent workplaces with sig-

Table 2. Mean values and standard deviation of the relative humidity in the milking parlor by milking sequence and reporting season

Milking sequence	Number n	Relative humidity, %			
		X ± Se	SD	Min	Max
Summer					
Morning	9	63.5± 2.82	8.48	56.3	78
Midday	9	59.5±2.08	6.23	50	67
Evening	9	64.8±1.44	4.33	59.4	72.1
Autumn					
Morning	6	62.7±3.25	7.97	50	73
Midday	6	66.7±6.06	14.83	52.8	80.9
Evening	6	73±5.66	13.86	54.4	85.5
Winter					
Morning	3	73.9±1.78	3.09	71.1	77.2
Midday	3	89.2±0.45	0.78	88.3	89.8
Evening	3	84.1±0.55	0.95	83.2	85.1
Spring					
Morning	9	69.7±3.61	10.84	51.6	87.8
Midday	12	55.7±3.26	11.30	40.6	69.7
Evening	12	63.9±1.79	6.20	50.6	69.7

nificant moisture release (milking parlors are such places) during the warm period, but the problematic high values of relative humidity were registered during the winter and considerably exceed 75% relative humidity.

Herbut et al. (2015) reported at a temperature of 24°C high relative humidity in the milking parlor of 85 – 90%, which exceeds the allowable values and contributes to the development of heat stress. These values gradually deteriorate up to the end of milking.

The thermal state of the indoor environment is influenced by the relative humidity of the air. The high content of water vapor in the air reduces the possibility of cooling the body of a person or animal by evaporation. This can cause heat stress at relatively low indoor temperatures. The relative humidity should ideally be in the range of 40 – 80%. Wet air is a good conductor of heat. Long-term exposure to relative humidity above 85% adversely affects the body and also shows insufficient level of ventilation (Papez & Kic, 2015).

Figure 4 presents mean values of the relative humidity of the air in the milking parlor and outside it in the open air in the area of the farm by season of reporting. No drastic differences between the reported values inside and outside were reported. The differences for all seasons were not statistically significant. Normally, higher humidity values were reported inside than outside because the milking process is accompanied by frequent washing with water, which increases the humidity inside. An exception was the autumn season, where the outside reported humidity was higher than the inside one, this was due to the quite rainy autumn, as rainfall was often observed during the humidity reporting. Herbut et al. (2012) also found that the relative humidity in the milking parlor is similar to the humidity in the outside air.

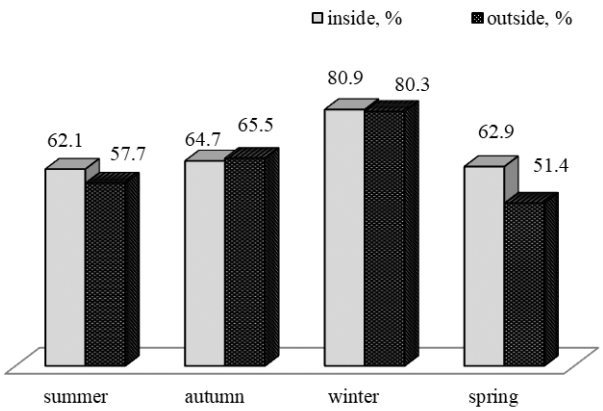

Fig. 4. Mean values for relative humidity in the milking parlor and outside by seasons

In the milking parlor a very low air velocity was registered (lack of ventilation), which cannot reduce the humidity values. The ventilation system in the milking parlor is necessary to ensure a continuous exchange of air in order to avoid an increase in both temperature and relative humidity (Herbut et al., 2012). The authors also found that on large farms, milking takes place on several successive technological groups of cows, which leads to a gradual deterioration of temperature and humidity in the milking parlor after each group, so that the comfort of the milker's workplace decreases during the milking session.

The combined effect of temperature and humidity is included in the temperature-humidity index (THI). This index is widely used to describe heat stress and is also a good indicator of environmental stress conditions (Armstrong, 1994; Zejdova et al., 2014). It is recommended when assessing the thermal comfort of the workplace, especially for activities related to increased use of water in enclosed spaces, such as milking parlors. High values of air humidity can lead to thermal stress for workers at lower than the normative values of air temperature.

Table 3 shows the average values and standard deviation of the temperature-humidity index in the milking parlor by milking sequence and reporting season.

The lowest values of THI in the milking parlor were reached in the autumn for evening milking – 51.4. The highest values for this indicator were reached during the summer season for midday milking of 75.6. In the current legislation

Table 3. Average values and standard deviation of the THI in the milking parlor by milking sequence and reporting season

Milking sequence	Number n	THI			
		X ± Se	SD	Min	Max
Summer					
Morning	9	70.1±0.33	0.99	68.5	71.4
Midday	9	75.6±0.70	2.11	72.9	80.0
Evening	9	74.5±0.46	1.37	72.1	76.1
Autumn					
Morning	6	54.9±1.00	2.46	51.2	57.9
Midday	6	53.3±1.70	4.18	48.9	57.8
Evening	6	51.4±1.63	4.00	47.2	55.1
Winter					
Morning	3	54.4±0.79	1.36	52.9	55.6
Midday	3	56.2±0.39	0.67	55.6	56.9
Evening	3	55.9±0.70	1.22	54.7	57.1
Spring					
Morning	9	65.5±1.78	5.35	58.1	72.9
Midday	12	71.3±2.09	7.25	59.1	78.1
Evening	12	67.8±2.40	8.30	53.5	74.1

in the country there are no requirements regarding the values of THI. According to Dragotă (2003) THI values up to 65 are in the comfort zone for humans, from 66-79 are in the zone of increased attention and over 80 danger zone. Referring the results obtained to this recommendation for the summer season and partly for the spring season, there were THI values reaching the zone with increased attention. For the summer months the values were over 70, and there were days with values of 80. This means that for 4 – 5 months of the year the milkers were exposed to unfavorable temperature and humidity conditions.

The presented results show that the working conditions in the milking parlor imply exposing the workers to risk for their health, especially during the warm months of the year. Installing fans in the milking parlor could reduce this effect.

Other studies showed the same results. Papez & Kic (2015) conclude from the results of measurements in several milking parlors that heating and ventilation is insufficient. During the summer the working temperature in the milking parlor corresponds to the outside temperature. The inside relative humidity is below the critical limit of 85%, however, it is higher than the outside relative humidity.

According to Gooch & Bickert (1999) a good milking parlor environment requires a properly designed, installed, operated and maintained ventilation system. The purpose of the ventilation system in the milking parlor is to regulate the temperature, relative humidity and odor levels within comfortable limits for both the milker and the cows. Proper ventilation is also important for maintaining the quality of the milk. A comfortable work environment will increase worker productivity and both quality and job satisfaction.

Conclusion

The established values of the air temperature inside the milking parlor are significantly higher by 5 – 6°C in the spring-summer season and lower by 4 to 6°C in the autumn-winter season than the admissible ones regulated by the current ordinance in our country, reaching threatening values that can harm the health of workers. The average values of the relative humidity in the milking parlor, especially during the winter season, considerably exceeded the maximum allowable values regulated by the current regulations for this indicator, which is a prerequisite for the occurrence of various diseases in staff. THI values for most of the year were also above the recommended norms for comfort in the workplace. For the summer season and partly for the spring season THI values have reached levels in the zone with increased attention (from 66 to 79). For the summer months the values were over 70, and there were days with values of 80. This means that for 4 – 5 months of the year milkers were exposed to unfavorable temperature and humidity conditions. It is necessary for the current regulations in our country to be updated and to be more specific about the type of work that is performed. It would be good the THI to be included in these regulations as it is a widely used index around the world to determine temperature comfort in humans. The construction of a ventilation system in the older milking parlors could contribute to improving the working conditions in them.

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