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Effect of temperature and relative humidity on the milk production of dairy cows

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Original article

Abstract

The aim of this study was to evaluate the influence of environmental housing conditions on the milk yield of dairy cows. Measurements were taken in the summer period from June to September, 2020 and in the winter period during January, 2021 on a large-capacity farm of Holstein Friesian cattle. Cows were housed in free stall barn with the lying boxes and selected during the second or third lactations, in the summer period from the 51st day to the 135th day and in the winter period from the 64th day to the 120th day of lactation. The average temperature in the housing was 23 °C in summer, and 7.05 °C in winter. The average THI (thermal humidity index) value in summer was 70.43, but during the day the THI values sometimes reached 75. The dairy cows were therefore exposed to heat stress during summer. Increasing THI and temperature values negatively affected the milk yield, as there was a negative correlation between both THI and milk yield ($r = -0.641$; $p < 0.01$) and temperature and milk yield ($r = -0.637$; $p < 0.01$). Milk production in winter was at 58.77 kg per day and in summer at 49.55 kg per day. In the summer, the milk had a significantly lower content of fat ($p < 0.05$), proteins ($p < 0.001$), lactose ($p < 0.001$), minerals ($p < 0.001$) and conversely, a higher number of somatic cells ($p < 0.01$). These results show that worse environmental conditions during the summer negatively affected the level of milk yield and the composition of the cows' milk.

Keywords

- dairy cows
- temperature
- relative humidity
- milk yield

Authors contributions

A – Conceptualization
B – Methodology
C – Validation
D – Data collection
E – Data analysis
F – Writing – original draft preperation
G – Writing, reviewing & editing
H – Project administration

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Conflict of interest

None declared.

Introduction

Animal production and health depend on the conditions of the environment in which they live. A favorable livestock environment is the one that not only ensures the optimal productivity, but also meets the animal health needs and their natural behavior [1]. Extremely low and high temperatures are associated with lower milk yield [2]. Adaptation and acclimatization to heat is more demanding than adaptation and acclimatization to cold, because it is easier to increase heat production with adequate food than to reduce heat production due to the metabolic processes necessary to sustain life [3]. Modern cowsheds must provide dairy cows with suitable environment conditions and welfare. Currently, the major problem in housing is a period of high summer temperatures, when it is necessary to protect dairy cows from the heat stress. During the periods of high temperatures, feed intake decreases with a direct impact on the milk yield [4]. In addition, with the steadily warming global climate and the intensification of hot periods, dairy cows are subjected to even more severe heat stress [5]. Animals in northern latitudes may experience a kind of heat stress, although the summer season is relatively short but hot and the drop in night temperatures is minimal. Results of the heat stress are considered total annual economic losses resulting from the reduced milk production, reduced dairy reproduction and the increased culling of animals [6]. In animals that are stressed by heat, digestion is slowed, which is manifested by the reduced feed intake, worsening of the rumen activity [7]. The temperature and humidity index (THI) is widely used to assess heat stress in dairy operations [8]. According to Moallem et al. [9], the major negative effect of the high heat-humidity index (THI) is a decrease in the rumination period, which leads to a reduction in dry matter intake and a consequent decrease in milk yield. Bernabucci et al. [10] report that a reduced nutrient intake in the heat-stressed cows contributes to a reduction in milk synthesis to about 35%. Due to the gradual global warming, an increase in heat stress problems can be expected in the near future [11].

In connection with this issue, the aim of the work was to monitor the impact of environmental conditions in the housing on the milk yield of dairy cows.

Materials and methods

Biological material and climate of the farm

The experiment was carried out on a farm in Western Slovakia with the Holstein-Friesian cattle. The measurements took place during summer and winter. The monitored dairy cows were on the 2nd and 3rd lactations. In the summer, 35 dairy cows were monitored from the 51st to the 135th day of lactation and in the winter period, 32 dairy cows from the 64th to the 120th day of lactation. Different animals were monitored during the summer and winter periods, so approximately the same stage of lactation was chosen.

The farm was located in a warm climatic area, which has an average of 50 or more summer days per year (with a daily maximum ≥ 25°C). The average air temperature in January was −1 to −2°C, in July 18 to 21°C. The annual average is 9 to 11°C.

Housing and feeding

The farm uses free stall barn with the lying boxes. The floor in the lying boxes is provided with water mattresses, on which sawdust with lime is spread. Effective cooling velocity cyclone fans installed every 9 m were used for the air exchange. In addition, dairy dew technology was used in the cowsheds if cooling during high temperatures in the summer was needed. Cows were milked 2 times per day in rotary milking parlour and each milking was recorded for each cow. During the hot summer days, the cows were cooled by fans in the waiting room before milking.

The animals were fed ad libitum, once a day (at 7 o'clock in the morning) with a total mixed ratio. The feed was rolled over regularly at 2-hour intervals. The animals had the ad libitum access to water. The composition of the total mixed ratios in winter and summer were same and as follows: corn silage 60%, corn cob mix 4%, triticale silage 16%, straw 1%, supplementary feed mixture 17%, water 2%.

Measurements and analysis

Measurements of the environmental conditions in the housing were performed in the summer period from the 12th June, 2020 to the 3rd September, 2020 and in the winter period from the 1st January, 2021 to the 31th January, 2021. We measured temperature and relative humidity using the HDL – TRH temperature and humidity data logger (Hivus s.r.o., Slovakia) at hourly intervals. The Thermal Humidity Index (THI) was calculated, from the measured values of temperature (T) [°C] and relative humidity (RH) [%] using the formula described by Hahn et al. [12]:

$$THI = 0.8 \cdot T + [(T - 14.4) \cdot RH] / 100 + 46.4 \quad (1)$$

Data on the milk yield and milk composition of dairy cows were monitored daily during the experiment in both summer and winter periods. The milk yield was evaluated based on the average daily milk production per dairy cow (kg per day). Similarly, the chemical composition of milk and the number of somatic cells (number per ml) were monitored every day. Within the chemical composition, we monitored the content of fat (in %), protein (in %), lactose (in %) and minerals (in %) using the FTIR infrared spectrophotometry.

Statistical analysis

Statistical analysis of the obtained results was performed in the IBM SPSS Statistics 20 Program. The Analysis of Variance (ANOVA) was used to assess the effects of the season on the monitored milk content parameters and the milk yield. The analysis was performed according to the following model equation:

$$Y_{ij} = \mu + S_i + e_{ij} \quad (2)$$

where Y_{ij} is an indicator of the milk content or milk yield, μ is the overall mean, S_i is the fixed effect ($n = 2$; 1 summer, 2 winter), e_{ij} is the random error.

Pearson's correlation coefficient was used to calculate the dependencies between the milk yield indicators and environmental conditions in the housing.

Results and discussion

Table 1 and Figure 1 show a comparison of temperatures, relative humidity, THI and an average daily production of dairy cows in the summer and winter seasons. In the summer period, the average temperature in the housing was 23°C, ranging from 15.35°C to 27.51°C. In winter, the average temperature was 7.05°C and ranged from −1.78°C to 11.37°C. The average relative humidity was higher in winter (78.86%, ranging from 59.34 to 86.42%) than in summer (66.89%, ranging from 46.45 to 84.42%). It follows from the above results, as well as from the findings of other authors, that summer is a risk period in terms of the heat stress [13–15].

Figure 1 shows a gradual decrease in the summer performance, which decreased from about 55 to 43 kg/day from the beginning to the end of the measurements, as a result of the long-term high temperatures. According to Anzures-Olvera et al. [15], the average milk production was demonstrably higher ($p < 0.01$) in winter, which was similar to ours. The demonstrable negative dependence between the temperature and efficiency ($p < 0.01$), but also the THI and efficiency ($p < 0.01$) also results from the correlation analysis given in Table 2. The threshold THI in which a dry matter intake decreases [16] and milk production decreases [17] is THI ≥ 72. According to Zimbelman et al. [18], the threshold value is even lower for high-yielding dairy cows (≥ 35 kg per day) (THI 68). Similarly, Markovich [19] has found that milk production in the Holstein breed begins to decrease at THI 65. During the summer, the THI was above 75, with an average THI of 70.43. Based on the findings of the above mentioned authors and the results obtained during the

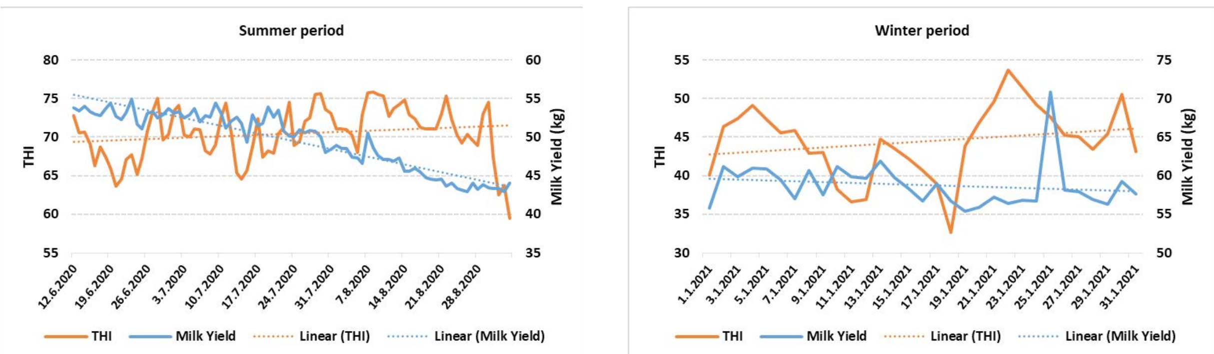

Figure 1. Thermal Humidity Index (THI) and milk yield in summer and winter period

Table 1. Season effect on the temperature and relative humidity and milk composition

Parameter	Season	Mean	St. dev.	Min.	Max.	Significance
Temperature (°C)	Summer	23.00	2.51	15.35	27.51	***
	Winter	7.05	2.74	-1.78	11.37	
Relative humidity (%)	Summer	66.89	8.17	46.45	84.28	***
	Winter	78.86	5.58	59.34	86.42	
THI	Summer	70.43	3.41	59.46	75.86	***
	Winter	46.16	6.01	32.67	67.59	
Milk yield (kg per day)	Summer	49.55	3.77	42.94	54.97	***
	Winter	58.77	2.91	55.43	70.83	
Fat (%)	Summer	3.71	0.101	3.42	4.01	*
	Winter	3.76	0.118	3.52	4.07	
Protein (%)	Summer	3.44	0.072	3.30	3.57	***
	Winter	3.57	0.028	3.51	3.63	
Lactose (%)	Summer	5.06	0.073	4.85	5.20	***
	Winter	5.2	0.04	5.12	5.29	
Minerals (%)	Summer	0.71	0.01	0.68	0.74	***
	Winter	0.74	0.007	0.73	0.76	
Somatic cells (count per ml)	Summer	144 797	33 109	66 500	232 500	**
	Winter	131 500	11 582	107 000	152 000	

* $p < 0.05$, ** $p < 0.01$; *** $p < 0.001$

experiment, it can be stated that the dairy cows were exposed to heat stress in the summer.

Different environmental conditions in the housing had a provable effect on the chemical composition of milk. In summer, there was a statistically significant decrease in the content of fat ($p < 0.05$), protein ($p < 0.001$), lactose ($p < 0.001$) and minerals ($p < 0.001$) in milk. In contrast, there was recognized a demonstrable increase in the somatic cell count ($p < 0.01$). The fat content of milk was lower by 0.08% in the summer period than in winter. Increase in the fat content in milk under hot conditions can be influenced by the addition of suitable energetic feeds. Moalem et al. [9] found that in hot and humid environment, the addition of fat to the feed ration had a positive effect on increasing the fat content of milk, while on the contrary, in the group of cows with the addition of corn in the feed ration there was a decrease in the fat content compared to the control group. In contrast to the results of our experiment, Anzures-Olvera et al. [15] report that milk had a higher content of fat and protein during the summer ($p < 0.01$), but the number of somatic cells was similar to ours in the winter. However, most studies report that fat and protein content decrease due to heat stress [20–22]. The correlations between the milk yield indicators and environmental conditions are shown in Table 2. High temperature and THI had a negative effect on the quantity and quality of the cow's milk. Similarly, Zejdová et al. [3] have found a negative correlation between the amount of milk produced and the temperature and also between the amount of milk and THI. Mohammed and Mahmound [23] also disclosed that high THI is associated with higher SCC and with a reduction of milk yield and quality, therefore potentially reduction of both welfare and economic return. On the contrary, the correlation analysis has showed that higher humidity has a positive effect on the milk production. This was caused by the fact that in winter there was a higher humidity in the housing, but dairy cows were not exposed to extreme temperatures. High humidity in the housing is associated with animal pollution and a higher incidence of pathogens in the tissues [24], leading to a predisposition to mastitis and milk contamination [25].

Table 2. Correlation analysis between the milk yield, temperature, relative humidity and THI

	Temperature	Humidity	THI
Milk Yield	−0.637**	0.389**	−0.642**
Fat	−0.210*	−0.032	−0.224*
Protein	−0.593**	0.314**	−0.603**
Lactose	−0.693**	0.412**	−0.696**
Minerals	−0.655**	0.348**	−0.663**
SC	0.202*	−0.041	0.210*

* $p < 0.05$, ** $p < 0.01$; *** $p < 0.001$

Conclusions

Results of this study have showed that worse relative humidity and temperature during the summer negatively affected the level of the milk yield and the composition of the cows' milk. The effect of the heat stress in milk reduced the content of fat, protein, lactose and minerals. In contrast, the number of somatic cells increased. Due to the ongoing climate changes, a further increase in summer temperatures can be expected in the future, therefore analyses of cow performance data in relation to environmental conditions are an important tool to enable farmers to take corrective measures.

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