Influence of temperature-humidity index (THI) on daily production of dairy cows in Mediterranean region in Croatia

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Abstract

With the aim of analysis the influence of temperature-humidity index (THI) on daily performance of dairy cows in Croatian Mediterranean region, 217,509 test-day records collected from January 2005 until April 2010 were extracted from HPA (Croatian Agricultural Agency) database. Milk recording in Croatia occurs according to the alternative milk recording method every four weeks, therefore, daily production of milk yields and components was projected using projection parameters estimated in authors' earlier research (Gantner, 2008). Logical control of data was performed according to ICAR standards (2003). The yields recorded after the 500th lactation day was deleted from the dataset.

According to the parity, cows were divided into three classes (heifers, cows in second lactation and cows in third and higher lactations) while, regarding the calving date, cows were divided in two calving season subgroups. According to the test date, four measuring season subgroups were created. Based on temperature and relative humidity recorded in stable at each milking control the daily temperature-humidity index (THI) values were calculated using the equation by Kibler (1964).

For estimation of the influence of exceeded THI (above critical value – 72) on daily production of dairy cows statistical model that take into account effects of lactation stage, breed, calving season, measuring season as well as effect of THI group (T_1 – THI under critical value; T_2 – THI above critical value) was used. The significance of differences between the means of the daily milk, fat, protein and lactose yield, as well as between the means of the daily fat, protein, and lactose content within the THI classes in regard to parity classes was tested with Scheffe test. For the statistical analysis and the figures drawing the SAS/STAT package was used (SAS Institute Inc., 2000).

The exceeded THI significantly decrease daily milk, fat, protein and lactose yield in heifers and cows in third and higher lactations. In second lactation determined decrease was not significant. Highly significant decrease of daily fat and protein content was determined in all cows, regardless the parity. The daily lactose content was not significantly influenced by enhanced value of THI. Management strategies are needed to minimize heat stress and to attain optimal cows' production in climatic condition of Croatian Mediterranean region.

Keywords: temperature-humidity index, daily milk yields and components, dairy cows, Mediterranean region

Introduction

Heat stress could be reason of the significant increase of production cost in the dairy industry. Armstrong (1994) noticed that the relative daily cows' production is constant when temperatures are low and medium, while after passing a threshold, starts to decrease. The rate of decline increases with rising temperatures. Exposition of dairy cattle to high ambient temperatures (Ta), high relative humidity (RH) and solar radiation for extended periods decrease the ability of the lactating dairy cow to disperse heat. At the same time, lactating dairy cows create a large quantity of metabolic heat. So, accumulated and produced heat joined with decreased cooling capability induced by environmental conditions, causes heat stress in the animals. Finally, heat stress induces increase of body temperature. Johnson (1980) observed that when the body temperature is significantly elevated, feed intake, metabolism, body weight and milk yields decrease to help alleviate the heat imbalance. Johnson et al. (1962) determined that with the termination of the hot season, in high-producing cows, the productivity does not completely return to normal since the energy deficit cannot be fully compensated. The permanent drop in the current lactation is proportional to the length of the heat stress.

The temperature-humidity index (THI) could be used to determine the influence of heat stress on productivity of dairy cows. Milk production is affected by heat stress when THI values are higher than 72, which corresponds to 22°C at 100% humidity, 25°C at 50% humidity, or 28°C at 20% humidity (Du Preez et al., 1990). Johnson (1980) reported that, when THI reaches 72, milk production as well as feed intake begins to decrease. The amount of milk yield decrease during the summer period in comparison to the winter period for Holstein cows about 10% to 40% (Du Preez et al., 1990). Under Mediterranean climatic conditions, milk yield drops by 0.41 kg per cow per day for each point increase in the value of THI above 69 (Bouraoui et al., 2002). Beside changes in milk yield, heat stress could also cause changes in milk composition, somatic cell counts (SCC) and mastitis frequencies (Rodriguez et al., 1985, Du Preez et al., 1990).

The objective of this research was to evaluate the effect of temperature-humidity index on daily production of dairy cows under climate conditions in Croatian Mediterranean region.

Material and methods

With the aim of analysis the influence of temperature-humidity index on dairy cows daily performance in Croatian Mediterranean region, 217,509 test-day records collected from January 2005 until April 2010 were extracted from HPA (Croatian Agricultural Agency) database. Milk recording in Croatia occurs according to the alternative milk recording method every four weeks when, depending of the particularly farm, the HPA control assistant (A) or the farmer (B) measures morning or evening milk yield, notes initial time of control milking and initial time of previous milking, and, for analysis of milk composition, takes milk sample from each lactating cow. For analysis of milk fat, protein and lactose content MilkoScan 133 B was used. The interval between successive milkings, required for projection of daily values, was computed as the time from the beginning of previous milking to the beginning of control milking. Daily production of milk yields and components was projected using projection parameters estimated in authors' earlier research (Gantner, 2008). Logical control of data was performed according to

ICAR standards (2003). The yields recorded after the 500th lactation day was deleted from the dataset.

According to the parity, cows were divided into three classes, that is heifers (P_1), cows in second lactation (P_2) and cows in third and higher lactations (P_3). Variability of analyzed traits in regard to parity classes is shown in table 1.

Table 1. Description of dataset used for analysis (n = 217,509).

Parameter	Parity		
	P_1	P_2	P_3
Daily milk yield, kg	14.55±5.95	15.23±6.11	15.75±6.30
Daily fat content, %	4.31±0.85	4.30±0.90	4.18±0.90
Daily fat yield, kg	0.61±0.25	0.64±0.27	0.65±0.28
Daily protein content, %	3.53±0.44	3.56±0.46	3.49±0.46
Daily protein yield, kg	0.51±0.20	0.53±0.20	0.54±0.20
Daily lactose content, %	4.59±0.21	4.51±0.22	4.43±0.25
Daily lactose yield, kg	0.67±0.28	0.69±0.28	0.70±0.29

According to the test date, four measuring season subgroups were created (S_1 – spring – including the period from April till June; S_2 – summer – including the period from July till September; S_3 – autumn – including the period from October till December; and S_4 – winter – including the period from January till March). Cows were divided in two calving season subgroups regarding the calving date (C_1 and C_2 that include animals calved in spring/summer and autumn/winter season).

The temperature and the relative humidity in stable were recorded at each milking. The daily temperature-humidity index (THI) values were calculated using the equation by Kibler (1964):

$$THI = 1.8Ta - (1 - RH)(Ta - 14.3) + 32 \quad (1)$$

where:

Ta – measured ambient temperature in °C, RH – relative humidity as a fraction of the unit. According to the value of the temperature-humidity index (THI), two THI subgroups were created (T_1 where $THI \leq 72$; and T_2 where $THI > 72$).

For estimation of the influence of temperature-humidity index (THI) on daily production of dairy cows that is daily milk, fat, protein and lactose yield, as well as, daily fat, protein, and lactose content following fixed – effect model was used:

$$y_{ijkl} = \mu + b_1(d/305) + b_2(d/305)^2 + b_3 \ln(305/d) + b_4 \ln^2(305/d) + B_i + C_j + S_k + T_l + e_{ijkl} \quad (2)$$

where:

y_{ijkl} = predicted daily performance (yield or content),
μ = intercept.

b_i = regression coefficients of Ali and Schaeffer lactation curve (1987),
d = lactation stage (days),
B_i = effect of breed (i = Holstein; Simmental),
C_j = effect of calving season (j = 1 – spring/summer; 2 – autumn/winter),
S_k = effect of measuring season (k = 1 – spring; 2 – summer; 3 – autumn; 4 – winter),
T_l = effect of THI group (l = 1 – THI ≤ 72; 2 – THI > 72),
e_{ijkl} = residual.

The significance of differences between the means of the daily milk, fat, protein and lactose yield, as well as between the means of the daily fat, protein, and lactose content within the THI classes in regard to parity classes was tested with Scheffe test. For the statistical analysis and the figures drawing the SAS/STAT package was used (SAS Institute Inc., 2000).

Results and discussion

Variation in the ambient temperature (Ta), relative humidity (RH), the temperature-humidity index (THI) in the stable, as well as the number of days with critical THI (> 72) noted during the measuring seasons is reported in table 2.

Table 2. Microclimate conditions in the stables in accordance to the measuring season.

Parameter	Measuring season			
	Spring (S_1)	Summer (S_2)	Autumn (S_3)	Winter (S_4)
Temperature, °C	20.64±5.53	22.82±4.77	14.85±5.14	12.56±4.71
Relative humidity, %	64.90±12.86	68.76±11.53	70.49±10.62	67.88±10.97
Temperature-humidity index (THI)	66.88±7.99	70.38±7.06	58.53±7.69	55.07±6.91
Number of days with THI > 72	14	32	0	0

S_1 – spring – period from April till June; S_2 – summer – period from July till September; S_3 – autumn – period from October till December; S_4 – winter – period from January till March

During the spring season that include period from April till June, average ambient temperature and relative humidity were 20.64±5.53°C and 64.90±12.86%, respectively. Mean THI was 66.88±7.99 and during 14 days critical THI was exceeded (figure 1A). In the summer season (including period from July till September) average Ta were 22.82±4.77°C, RH were 68.76±11.53%, THI were 70.38±7.06, resulting in 32 days with THI above critical (figure 1B).

Berman et al. (1985) suggested that the upper limit of ambient temperatures at which Holstein cattle may maintain a stable body temperature is 25 to 26°C, and that above 25°C practices should be instituted to minimize the rise in body temperature. Bianca (1965) determined decrease in daily milk yield of Holstein, Jersey and Brown Swiss cows in amount of 3, 7 and 2% of normal at a temperature of 29°C and 40% relative humidity. Increase of relative humidity to 90% induces additional decrease of milk yield for 31, 25, and 17% of normal yield.

A mean daily THI in value of 72 is considered to be the critical point at which milk yield is reduced (Johnson, 1987). Increasing THI in the range of 71 to 81 reduced the milk yield and intake of feed and water for dairy cows (Johnson et al., 1963). The effect was greatest when THI exceeded 76.

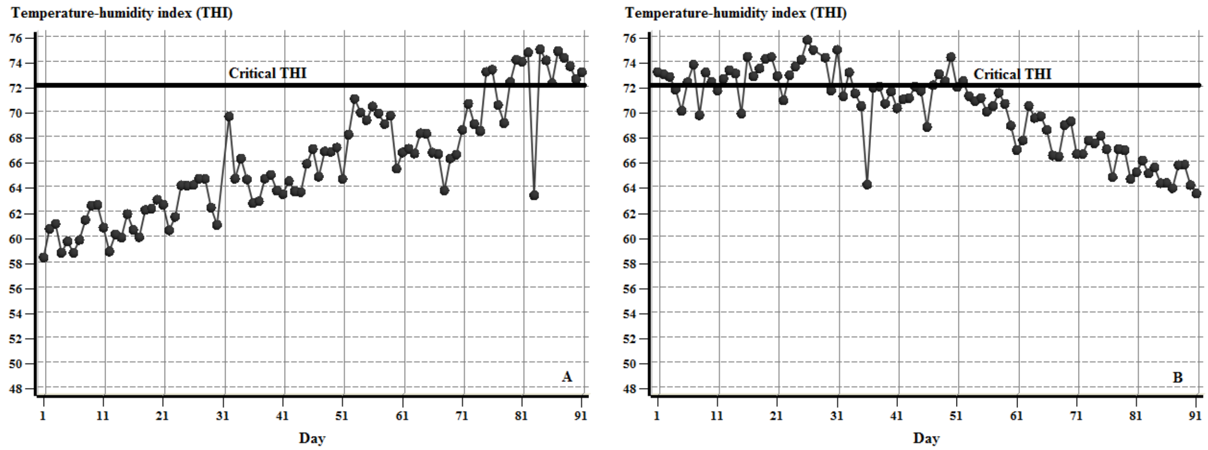

Figure 1. Average temperature-humidity index during the spring (A) and the summer (B) period.

Variations in average daily THI, during autumn (period from October till December) and winter season (period from January till March) and winter period are shown on figure 2C and 2D. As expected, lack of heat stress conditions (THI value significantly lower than critical), characterized these seasons. Regarding the average ambient temperature and the relative humidity, in the autumn season 14.85±5.14^{o}C and 70.49±10.62% were measured. In the winter season Ta = 12.56±4.71^{o}C, and RH = 67.88±10.97% (table 2).

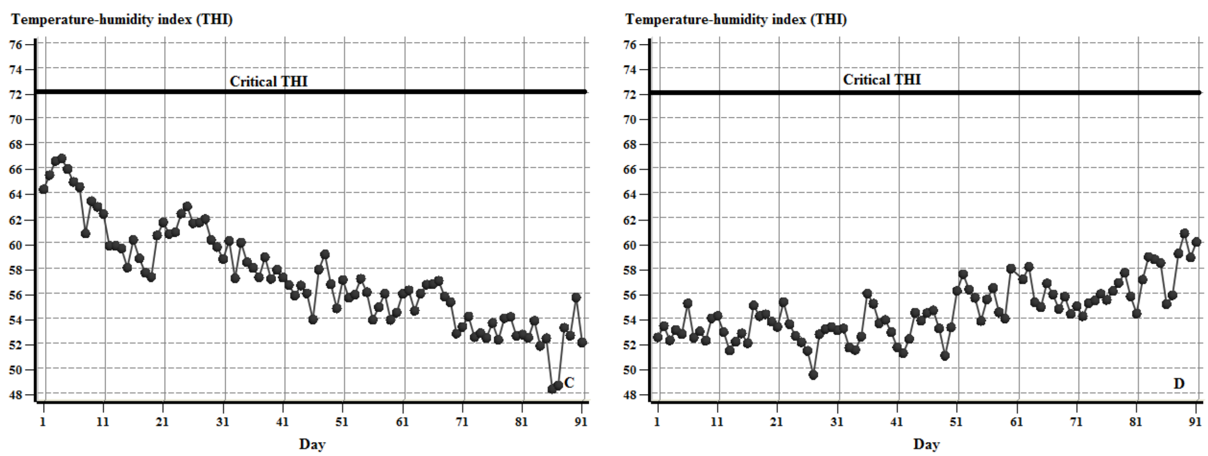

Figure 2. Average temperature-humidity index during the autumn (C) and the winter (D) period.

Effect of exceeded THI on daily milk yields and components in relation to parity classes are shown in table 3. Highly significant ($P < 0.01$) decrease of daily milk yield due to enhanced THI was observed in cows in first and third parity class, while in cows in second lactation determined decrease was not significant ($P > 0.05$).

The THI higher than 72 also induce highly significant ($P < 0.01$) decrease of daily fat and protein content in all cows, regardless the parity class. The daily lactose content was not significantly influenced by enhanced value of THI. Regarding the daily fat, protein and lactose yields, significant decrease as consequence of THI values above critical was determined in heifers and cows in third and higher lactations.

Table 3. Least square means of daily milk yields and contents for THI groups in relation to parity classes.

Parameter	Parity / THI group					
	P_1		P_2		P_3	
	T_1	T_2	T_1	T_2	T_1	T_2
Daily milk yield, kg	14.236^A	13.859^B	15.083^A	15.060^A	15.770^A	15.520^B
Daily fat content, %	4.301^A	4.241^B	4.296^a	4.257^b	4.180^A	4.126^B
Daily fat yield, kg	0.600^A	0.575^B	0.637^A	0.632^A	0.650^A	0.630^B
Daily protein content, %	3.536^A	3.480^B	3.574^A	3.510^B	3.502^A	3.452^B
Daily protein yield, kg	0.496^A	0.474^B	0.528^a	0.519^b	0.542^A	0.526^B
Daily lactose content, %	4.602^A	4.603^A	4.514^A	4.509^A	4.437^A	4.439^A
Daily lactose yield, kg	0.656^a	0.637^b	0.683^A	0.681^A	0.703^A	0.692^B

the values within classes of parity groups marked with the same letter are not significantly different (P > (0.01) 0.05)

Deteriorate effect of exceeded THI on daily milk yields and components were also observed by other authors. Ingraham (1979) estimated that milk yield reduction was 0.32 kg per unit increase in THI. Johnson et al. (1963) reported that the milk yield and the DMI (dry matter intake) exhibited significant declines (by 1.8 and 1.4 kg for each 0.55°C increase in rectal temperature) when maximum THI reached 77. A significant negative correlation between THI and DMI was determined for cows in the south-eastern U.S. (Holter et al., 1996; 1997). Same authors presume that the effect of THI is probably mediated through the effects of increasing body temperature on cow performance. Umphrey et al. (2001) reported that the partial correlation between milk yield and rectal temperature for cows in Alabama was −0.135. Ravagnolo et al. (2000) determined that milk yield declined by 0.2 kg per unit increase in THI when THI exceeded 72. Bouraoui et al. (2002) observed that the daily THI was negatively correlated to milk yield (r = –0.76) and feed intake (r = –0.24). Same authors also determined that milk yield decreased by 0.41 kg per cow per day for each point increase in the THI values above 69. West et al. (2002) reported that, during hot weather, the mean THI two days earlier had the greatest effect on milk yield, while DMI was most sensitive to the mean air temperature two days earlier. Milk yield for Holsteins declined 0.88 kg per THI unit increase for the 2-d lag of mean THI, while DMI declined 0.85 kg for each degree (°C) increase in the mean air temperature. The authors presume that the delayed impact of climatic variables on production could be related to altered feed intake, delay between intake and utilization of consumed nutrients, or changes in the endocrine status of the cow.

Decrease of daily fat (3.24 vs. 3.58%) and protein (2.88 vs. 2.96%) content, as well as decrease of daily fat (0.68 vs. 0.48) and protein (0.56 vs. 0.43) yields during summer period in regard to spring period was reported by Bouraoui et al. (2002). The depressions in milk fat and protein percentages associated with heat stress environments were also determined by Rodrigez et al. (1985). On the other hand, Knapp and Grummer (1991) found no significant decrease in fat percentage for cows under heat stress. The difference between results obtained in this research and those reported by Knapp and Grummer (1991) could be caused by use of total mixed rations (TMR) which probably alleviate milk fat depression commonly associated with heat stress by maintaining the intended forage to concentrate intake and, ensuring adequate fiber for proper rumen fermentation. In the same study Knapp and Grummer (1991) observed decrease of milk protein with increase of maximum daily temperature. The reduction in milk protein is probably caused by a decreased DMI and energy intake. Emery (1978) quoted that decreased levels of food intake during lactation are usually associated with decreased protein content.

Conclusions

The exceeded THI significantly decrease daily milk, fat, protein and lactose yield in heifers and cows in third and higher lactations. In second lactation determined decrease was not significant. Highly significant decrease of daily fat and protein content was determined in all cows, regardless the parity. The daily lactose content was not significantly influenced by enhanced value of THI. Management strategies are needed to minimize heat stress and attain optimal cows' production in climatic condition of Croatian Mediterranean region.

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