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HEAT STRESSED HOLSTEIN HEIFERS - THRESHOLD DETERMINATION IN CENTRAL CROATIA

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ABSTRACT

In the light of increasingly rapid climate change worldwide, and with the purpose of reduction of financial losses of dairy farmers and enabling the sustainable farming, the necessity of implementation of breeding values for heat resistance in breeding strategies, have become more and more pronounced. Estimation of breeding values requires determination of THI threshold value. Therefore, the objective of this research was to determine the THI threshold value for Holstein heifers in environmental conditions in Central Croatia. With that purpose individual test-day records of Holstein heifers with records of ambient temperature and relative humidity in the barns collected in regular milk recording from January 2006 to December 2012 were analysed. The THI threshold values for daily milk yield were determined by least square analyses of variance for each given THI value (from 65 to 76) using the PROC MIXED (SAS). The THI ≥ 65 cause significant change in Holstein heifers' daily production. Significant decrease of daily milk yield was observed at THI = 65 with estimated drop from 0.087 till 0.254 kg milk/day (THI from 65 – 76). The THI = 65, as the lowest value at which significant decrease in daily milk yield was determined was taken as the threshold value for Holstein heifers in Central Croatia.

Key words: Holstein heifers, heat stress, temperature-humidity index, threshold, Central Croatia.

INTRODUCTION

In the last few decades, we have witnessed more expressed and increasingly rapid climate change worldwide. Meaning, that in regions that at the time are not characterized as extreme climate conditions, in future dairy cattle will be exposed to the unfavourable climatic conditions (IPCC, 2007). In accordance with this forecast, Reiczigel et al. (2009) in Hungary determined increase of heat stress days/year (temperature-humidity index – THI > 68) from 5 to 17 in a period of 30 years. In dairy cattle breeding in indoor housing, the optimal microclimate conditions in the barns are necessary for the realization of the productive potential of individual cows. The interrelation between ambient temperature and relative humidity is important from the aspect of animal welfare, reproduction and finally profitability of dairy farm. Any extreme combination is potentially harmful. In environment with low temperature and high humidity, cows increase heat production and consume more feed in order to compensate body energy losses. When the animal is overheated, high humidity may lead to infections of respiratory tract or udder. On the other hand, high temperature and low relative humidity may dehydrate mucous membranes thus increasing vulnerability to viruses and bacteria (Romaniuk and Overby, 2005).

The combination of high temperature and high relative humidity has the most detrimental effect through inducing heat stress in cows. Under heat stress conditions, lactating cows tend to reduce their dry matter intake (DMI) and milk production (West et al., 1999). Moreover, besides milk production heat stress is associated with changes in milk composition, somatic cell counts (SCC) and mastitis frequencies (Bouraoui et al., 2002.; Collier et al., 2012; Correa-Calderon et al., 2004; Ravagnolo et al, 2000.; St-Pierre et al., 2003; West, 2003). Additionally, deteriorate effect on reproductive performances was also observed (Bohmanova et al., 2007; Ravagnolo et al., 2000). Numerous studies showed that the high producing cows are much more susceptible to heat stress than low producing cows (Bohmanova, 2006; Collier et al. 2006). Kadzere et al. (2002) suggested that, due to intensive genetic selection for milk production, the thermoregulation physiology of a cow have been changed. The high producing cows have larger frames and larger gastrointestinal tracts which allow digestion of more feed and result in more metabolic heat which consequently reduce cow's ability to maintain normal temperature at unfavourable conditions. Finally, high producing cows experience heat stress earlier than low producing since the thermoneutral zone of high producing cows is at lower temperatures. The most common measure of heat stress in dairy cows is the temperature-humidity index (THI) that present combination of ambient temperature and relative humidity and is a useful and easy way to assess the risk of heat stress (Kibler, 1964). Du Preez et al. (1990a, b) determined that milk production and feed intake is affected by heat stress when THI values are higher than 72. Bouraoui et al. (2002) put the threshold on 69, while Bernabucci et al. (2010) as well as Collier et al. (2012) on 68. Vitali et al. (2009) suggested that the risk of cow's death starts to increase when THI reaches 80. The significant decrease of daily milk traits (yield and contents) was also determined in Croatian environmental conditions with highest decline during summer period in Eastern and Mediterranean Croatia (Gantner et al., 2011). In many dairy-producing areas of the world heat stress condition represent a significant financial burden, for example in the USA between $897 million and $1,500 million per year (St-Pierre et al., 2003). There are many methods to decrease the impact of heat stress including the shading, cooling, nutrition (Kadzere et al., 2002; West, 2003) and selection for resistance on heat stress (Bohmanova, 2006). Ravagnolo et al. (2000) determine antagonistic relationship between cow's production and heat tolerance implying deteriorate effect of selection on productivity on cow's resistance to heat stress. The high yielding Holstein cows in Israel is good example that selection on production could be successful in terms of heat stress (Aharoni et al., 1999). Implementation of breeding values for heat resistance in breeding strategies would certainly reduce financial losses of dairy farmers and enable sustainable farming. Estimation of breeding values requires determination of THI threshold value. Therefore, the objective of this research was to determine the THI threshold value for Holstein heifers in environmental conditions in Central Croatia.

MATERIALS AND METHODS

Individual test-day records of Holstein heifers collected in regular milk recording performed by alternative milk recording method from January 2006 to December 2012 in Central Croatia were used for the analysis. Monthly, at each recording, milk yields were measured during the evening or morning milkings. Additionally, at each recording, ambient temperature and relative humidity in the barns were recorded. Logical control of milk data was performed according to ICAR standards (2003). Daily temperature-humidity index (THI) was calculated using the equation by Kibler (1964):

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

where Ta is average temperature in degrees Celsius and RH is relative humidity as a fraction of the unit. Records with lactation stage in (< 6 days and > 305 days), age at calving in (< 21 and > 36 months), missing or parity > 1, and missing or nonsense Ta and RH value were deleted from dataset. Data, provided by the Croatian Agricultural Agency, after logical control consisted of 153,305 test-day records from 21453 heifers reared on 1,750 farms in Croatia. Variability of ambient temperature (Ta) and relative humidity (RH) per recording year in Central Croatia is presented in Table 1.

Table 1. Descriptive statistics of ambient temperature (Ta) and relative humidity (RH) measured during the milk recording regarding the recording year in Central Croatia

Recording	**Ambient temperature (°C)**					**Relative humidity (%)**				
year	Mean	SD	CV	Min	Max	Mean	SD	CV	Min	Max
2006	17.0	7.28	42.7	-8.0	40.0	69.8	10.35	14.8	30.0	99.0
2007	16.6	6.72	40.4	-3.0	39.0	70.0	10.80	15.4	30.0	97.0
2008	16.2	6.80	41.8	-7.0	39.0	69.7	11.20	16.1	30.0	99.0
2009	16.6	7.21	43.4	-7.0	39.0	70.1	10.46	14.9	30.0	97.0
2010	15.2	7.36	48.5	-5.0	40.0	72.6	10.35	14.3	30.0	97.0
2011	16.2	7.99	49.4	-3.0	40.0	70.6	9.82	13.9	31.0	99.0
2012	16.1	7.87	48.9	-8.0	39.0	71.1	10.12	14.2	31.0	98.0

The THI threshold values for daily milk yield were determined by least square analyses of variance for each given THI value (from 65 to 76) using the PROC MIXED procedure in SAS (SAS Institute Inc., 2000). Following mixed model was used:

$$y_{ijklmn} = \mu + b_1(d_i/305) + b_2(d_i/305)^2 + b_3 \ln(305/d_i) + b_4 \ln^2(305/d_i) + S_j + A_k + T_l + e_{ijklmn}$$

where y_{ijklm} = estimated daily milk yield; μ = intercept; b_1, b_2, b_3, b_4 = regression coefficients; d_i = days in milk (i = 6 to 305 day); S_j = fixed effect of calving season class j (j = 1/2006 to 12/2012); A_k = fixed effect of age at calving class k (k = 21 to 36 month), T_i = fixed effect of THI class (l = 0 (*normal condition – values under the given threshold*) or 1 (*heat stress condition – values equal and above the given threshold*)), and e_{ijklm} = residual. The significance of the differences between the THI classes were tested by Scheffe's method of multiple comparisons. The lowest threshold value at which significant differences in milk yield was determined, was taken as the threshold value.

RESULTS AND DISCUSSION

Maximum daily relative humidity and ambient temperature measured during the milk recording in summer period in years 2006 – 2012 are presented in figure 1.

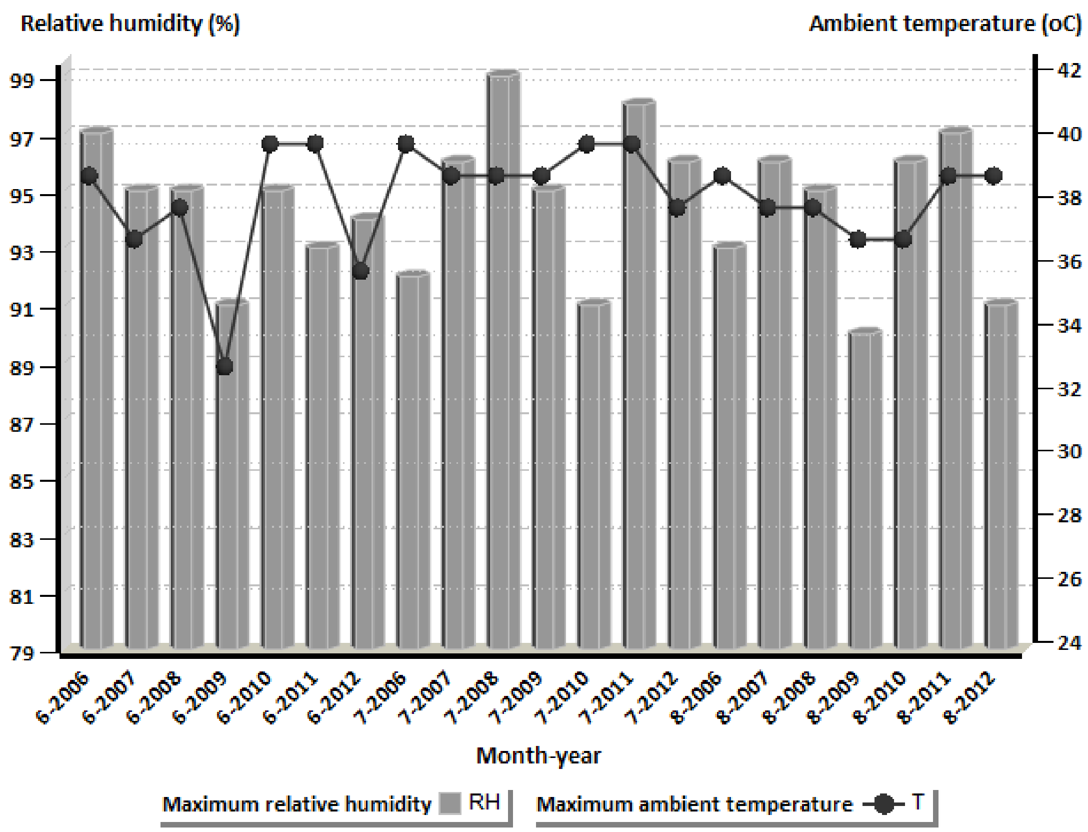

Figure 1 Maximum daily relative humidity and ambient temperature measured during milk recording

Least square means from analysis of variances regarding the fixed effect of THI class (0, 1) on daily milk yield are shown in Table 2. Environmental conditions in the barns with THI values in 65 caused significant, but small (0.087 kg/day) difference in daily production of Holstein heifers. Statistically highly significant decrease of daily milk yield was observed when THI value in the barns was above 65 that is in interval from 66 – 76, when, estimated drop in milk yield was from 0.157 till 0.254 kg/day. Highest decrease was determined in environmental condition characterised with THI = 68. The lowest value at which significant differences in milk yield was determined, was taken as the threshold value. Therefore, in environmental conditions in Central Croatia, as threshold value for Holstein heifers 65 was set. Significant drop in daily production of dairy cattle at the same THI value was also determined by Bernabucci et al. (2010) and Collier et al. (2012). Bouraoui et al. (2002) in a Mediterranean climate observed decrease in milk production of dairy cows in condition characterised with THI ≥ 69. In the environmental conditions of Eastern Croatia that characterise more extreme weather comparable to the Central, THI threshold value for the first parity Holsteins was set to 68, with the highest drop of 0.716 kg/day if THI =74 (Gantner et al., 2015).

Du Preez et al. (1990a, b) determined that dairy cows in Southern African conditions are affected by heat stress when THI values are higher than 72. The significant decrease of daily milk yield when THI ≥ 72 was also determined in Croatian and Mediterranean Croatia (Gantner et al., 2011). Bohmanova et al. (2007) in USA determined different threshold values regarding the region (72 in Georgia, and 74 in Arizona). The difference between determined threshold values could be due to better adapted cows, farm management or special housing characteristics.

Table 2. Least square means of daily milk yield regarding the given threshold value

ThHo	Ls0	Ls1	Estimated difference
THI65	**18.20 ± 0.098**	**18.11 ± 0.100**	**0.087 ± 0.038***
THI66	18.24 ± 0.098	18.00 ± 0.101	0.245 ± 0.039***
THI67	18.23 ± 0.098	18.01 ± 0.101	0.219 ± 0.040***
THI68	18.23 ± 0.097	17.98 ± 0.102	0.254 ± 0.041***
THI69	18.22 ± 0.097	18.01 ± 0.102	0.208 ± 0.042***
THI70	18.21 ± 0.097	18.01 ± 0.103	0.203 ± 0.043***
THI71	18.21 ± 0.097	17.99 ± 0.104	0.220 ± 0.045***
THI72	18.20 ± 0.097	17.98 ± 0.105	0.222 ± 0.046***
THI73	18.20 ± 0.097	17.97 ± 0.106	0.230 ± 0.048***
THI74	18.20 ± 0.097	17.98 ± 0.107	0.218 ± 0.051***
THI75	18.19 ± 0.097	18.03 ± 0.108	0.157 ± 0.054**
THI76	18.19 ± 0.097	18.00 ± 0.111	0.189 ± 0.058**

* ThHo – given threshold value; 0 – class under, and 1 – class above the given threshold value

CONCLUSION

Based on analysed data it could be concluded that THI ≥ 65 cause significant change in Holstein heifers' daily production. Significant decrease of daily milk yield was observed at THI = 65 with estimated drop from 0.087 till 0.254 kg milk/day (THI from 65 – 76). The THI = 65, as the lowest value at which significant decrease in daily milk yield was determined was taken as the threshold value for Holstein heifers in Central Croatia.

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