

Determination of the Effect of Daily Production Level of Primiparous Holstein Cows on Response to Heat Stress Conditions (THI Threshold) in Eastern Croatia

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Abstract

The goal of this paper was to determine the effect of daily production level of primiparous Holstein cows kept on dairy cattle farms in Eastern Croatia on response to heat stress conditions (THI threshold). In order to do this, individual test-day records with data on ambient temperature and relative humidity in the barns were analysed. The data were collected in regular milk recording from 2006-2012. The THI threshold values for daily milk yield were determined by least square analyses of variance for each given THI value (from 68 to 72) using the PROC MIXED (SAS). Low-producing cows experienced significant drop at THI=68, while in high-producing primiparous Holsteins the first significant drop in daily milk yield was observed when THI=69. Also, the amount of daily production drop depended on the cow's production level (0.155-0.256 kg/day in high-producing; 0.319-0.460 kg/day in low-producing). It could be concluded that the response of primiparous Holstein cows kept in Eastern Croatia to heat stress conditions depends on daily production level.

Key words: primiparous Holsteins, heat stress conditions, temperature-humidity index, daily production level, Eastern Croatia

Introduction

During the last decade climate change worldwide becomes indisputable. In accordance to IPCC forecasts (2007) regions worldwide that are not currently characterized by extreme climate conditions will become unsuitable for dairy cattle in the future due to being exposed to unfavourable climatic conditions. Furthermore, Reiczigel et al. (2009) determined the increase of heat stress days/year (temperature-humidity index – THI > 68) from 5 to 17 in Hungary in the period of 30 years. In farms where dairy cattle are kept in indoor housing, one of the main management tasks is to ensure optimal microclimate conditions in the barns. These conditions are necessary in order to realize the productive potential of individual cows. The correlation between temperature and relative humidity in the barn is important in terms of animal welfare, reproduction traits and dairy farm profitability. Any extreme combination of these two factors is potentially harmful. For instance, in barns with low temperature and high humidity cows tend to increase heat production and feed consumption in order to compensate body energy loss. On the other hand, when cows are overheated, high humidity may lead to infections of respiratory tract or udder (Vermunt and Tranter, 2011).

Romaniuk and Overby (2005) stated that high temperature in combination with low relative humidity may cause dehydration of mucous membranes thus increasing vulnerability to viruses and bacteria. The most detrimental effect is a combination of high temperature and high relative humidity through inducing heat stress in cows. In lactating cows, the heat stress conditions induce reduction of dry matter intake (DMI) and milk production (West et al., 1999). Moreover, beside milk production reduction, 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). Furthermore, negative effect on reproductive performances was also determined (Bohmanova et al., 2007; Ravagnolo et al., 2000). Many researches determined that high-producing cows are much more susceptible to heat stress than the low-producing ones (Bohmanova, 2006; Collier et al. 2006). Kadzere et al. (2002) suggested that the thermoregulation physiology of the cow has been changed due to intensive genetic selection for milk production. The high-producing cows have larger frames and larger gastrointestinal tracts allowing digestion of more feed resulting in more metabolic heat, which consequently reduces the cow's ability to maintain normal temperature at unfavourable temperature conditions.

Finally, high-producing cows experience heat stress earlier than low-producing cows since the thermoneutral zone of high-producing cows is at lower temperatures. The most common measure of heat stress level in dairy cows is the temperature-humidity index (THI). This index represents the 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 are affected by heat stress when THI values are higher than 72. Bouraoui et al. (2002) put the THI threshold at 69, while Bernabucci et al. (2010) as well as Collier et al. (2012) put it at 68. Vitali et al. (2009) suggested that the risk of cow's death started to increase when THI reached 80. The significant decrease of daily milk traits was also found in Croatian environmental conditions with the highest decline during summer period in Eastern and Mediterranean Croatia (Gantner et al., 2011). Heat stress condition causes significant financial burden in dairy production worldwide, for instance dairy production losses in the USA amounts to between \$897 and \$1,500 million per year (St-Pierre et al., 2003). The impact of heat stress could be decreased by shading, cooling and nutrition (Kadzere et al., 2002; West, 2003). Furthermore, a long-term method is selection for resistance on heat stress (Bohmanova, 2006). Ravagnolo et al. (2000) determined antagonistic relationship between the cow's production and heat tolerance implying deteriorating effect of selection on productivity and cow's resistance to heat stress.

. On the other hand, the high-yielding Holstein cows in Israel are a good example how selection on production could be successful in terms of heat stress (Aharoni et al., 1999). In order to cope with climate change and to reduce dairy farmers' financial losses caused by heat stress, the estimation of breeding values for heat resistance should be introduced in breeding strategies. This estimation requires determination of THI value when cows respond to inadequate environmental conditions (threshold value). The goal of this paper was to determine the effect of daily production level of primiparous Holstein cows kept on the dairy cattle farms in Eastern Croatia on response to heat stress conditions (THI threshold).

Material and Methods

The individual test-day records of the primiparous Holsteins collected in regular milk recording performed by the alternative milk recording method from January 2006 to December 2012 were used for statistical analysis. Monthly, milk yields were measured at each recording during the evening or morning milkings.

Additionally, ambient temperature and relative humidity in the barns were recorded at each milk recording. Logical control of milk data was performed in accordance with 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 Celsius degrees and RH is relative humidity as a fraction of the unit. Records with lactation stage in (<6 days and >305 days), age at first calving in (<21 and >36 months), missing or parity >1, and missing or nonsense Ta and RH value were deleted from dataset. In accordance with the production level, the cows were divided into two classes: high (≥ 25 kg) and low (< 25 kg). Data, provided by the Croatian Agricultural Agency, after logical control, consisted of 171,665 test-day records from 23,604 primiparous Holsteins kept on 1,805 dairy farms. The maximum values of ambient temperature and relative humidity measured from June until August per recording year in Eastern Croatia are presented in Table 1.

Tab. 1. Maximum values of ambient temperature and relative humidity measured during milk recordings of Holsteins from June until September according to the production year

Максималне вриједности амбијенталне температуре и релативне влажности ваздуха, мјерених током анализа млијека Холитајн крава, у периоду од јуна до септембра, по годинама

Year	June		July		August	
	Temp.*	Hum.	Temp.	Hum.	Temp.	Hum.
2006	37	97	36	90	39	91
2007	36	94	39	89	39	93
2008	33	96	38	96	35	95
2009	33	98	40	95	34	94
2010	34	97	36	98	37	98
2011	32	92	38	96	39	96
2012	37	98	39	97	40	91

*Temp. – ambient temperature, Hum. – relative humidity

The THI threshold values for daily milk yield were determined by least square analyses of variance for each given THI value (from 68 to 72) using the PROC MIXED procedure in SAS (SAS Institute Inc., 2000). The 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 = regression coefficients;

d_i = days in milk ($i=6$ to 305 day, lactation curve by Ali and Schaeffer, 1987);

S_j = fixed effect of calving season class j ($j=1/2006$ to 12/2012);

A_k = fixed effect of age at first 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*));

e_{ijklm} = residual.

The significance of the differences between the THI classes was tested by the Scheffe's method of multiple comparisons. The lowest threshold value at which significant differences in milk yield were determined has been taken as the THI threshold value.

Results and Discussion

Least square means obtained by analyzing variances regarding the fixed effect of THI class (0, 1) on daily milk yield of high-producing primiparous Holsteins are shown in Table 2. Environmental conditions in the barns that characterise THI values at 68 did not cause significant difference in daily milk production. The first statistically significant decrease of daily milk yield was observed at THI value 69. When THI value exceeded 69, the estimated drop in milk yield was from 0.155 to 0.256 kg/day. The highest decrease was determined in the environmental condition characterised by THI = 71.

Tab. 2. Least square means of daily milk yield (kg/day) of high-producing primiparous Holsteins in accordance to the given THI threshold value ($n = 11,093$)

Аритметичке средине дневног приноса млијека (kg/дану) високо продуктивних Холштајн крава у складу са датом вриједношћу THI (n = 11,093)

ThHo	Ls0	Ls1	Estimated difference	P value	Significance
THI68	29.34 ± 0.083	29.35 ± 0.093	0.009 ± 0.054	0.8643	n.s.
THI69	29.37 ± 0.083	29.22 ± 0.094	0.155 ± 0.055	0.0046	**
THI70	29.38 ± 0.083	29.14 ± 0.095	0.245 ± 0.057	< 0.0001	***
THI71	29.38 ± 0.083	29.12 ± 0.097	0.256 ± 0.060	< 0.0001	***
THI72	29.37 ± 0.083	29.17 ± 0.099	0.192 ± 0.062	0.0021	**

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

The lowest value, at which significant differences in milk yield were determined was taken as the threshold value. Therefore, in the environmental conditions of Eastern Croatia, THI threshold value for the high-producing primiparous Holsteins could be set to 69. Least square means obtained by analyzing variances regarding the fixed effect of THI class (0, 1) on daily milk yield of low-producing primiparous Holsteins are shown in Table 3. The first statistically significant decrease of daily milk yield was observed when the THI value was 68 (threshold value). The estimated drop in daily milk yield varied in the interval from 0.319 to 0.460 kg/day.

The highest decrease was observed when THI = 72. Similarly, significant drop in daily production for dairy cattle at the THI value being 68 was also determined by Bernabucci et al. (2010) and Collier et al. (2012).

Tab. 3. Least square means of daily milk yield (kg/day) of low-producing primiparous Holsteins in accordance to the given THI threshold value (n = 12.511)

Аритметичке средине дневног приноса млијека (kg/дану) ниско продуктивних Холштајн крава у складу са датом вриједношћу THI (n = 11,093)

ThHo	Ls0	Ls1	Estimated difference	P value	Significance
THI68	17.03 ± 0.065	16.71 ± 0.073	0.319 ± 0.042	< 0.0001	***
THI69	17.03 ± 0.065	16.71 ± 0.073	0.323 ± 0.042	< 0.0001	***
THI70	17.03 ± 0.065	16.67 ± 0.074	0.365 ± 0.043	< 0.0001	***
THI71	17.02 ± 0.065	16.70 ± 0.075	0.320 ± 0.045	< 0.0001	***
THI72	17.03 ± 0.065	16.57 ± 0.077	0.460 ± 0.048	< 0.0001	***

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

In a Mediterranean climate Bouraoui et al. (2002), the observed milk production decrease in the environmental condition characterized by THI ≥ 69, while Du Preez et al. (1990a,b) determined that dairy cows in Southern African conditions were affected by heat stress when THI values were higher than 72. The significant decrease of daily milk yield, when THI ≥ 72, was also determined in Eastern and Mediterranean Croatia (Gantner et al., 2011). In the USA Bohmanova et al. (2007) determined different threshold values regarding different regions (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.

Conclusion

Based on the analysed data it could be concluded that the response of the primiparous Holstein cows kept in Eastern Croatia to heat stress conditions depends on daily production level. Low-producing cows experienced significant drop at THI = 68, while in high-producing primiparous Holsteins the first significant drop in daily milk yield was observed when THI = 69. Also, the amount of daily production drop depended on the cow's production level (0.155 - 0.256 kg/day in high-producing vs. 0.319 - 0.460 kg/day in low-producing).

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Одређивање утицаја разине дневне производње првотелки Холштајн крава на одговор на услове топлотног стреса (ТН1 праг) у Источној Хрватској

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Сажетак

Циљ овог рада био је утврдити утицај нивоа дневне производње првотелки Холштајн крава држаних на фармама млијечних крава у Источној Хрватској на одговор на услове топлотног стреса (ТН1 праг). У том циљу, анализирани су индивидуални дневни записи са подацима о амбијеталној температури и релативној влажности у шталама. Подаци су скупљани у оквиру редовних контрола млијечности од 2006 до 2012. ТН1 праг за дневни принос млијека је одређена анализом варијансе најмањих квадрата за сваку дефинисану ТН1 вредност (од 68 до 72) коришћењем статистичког програма PROC MIXED (SAS). Краве са ниском продукцијом су имале значајан пад на ТН1 = 68, док је код високо продуктивних првотелки Холштајн крава први значајан пад производње млека уочен на ТН1 = 69. Такође, износ пада дневне производње зависи од нивоа дневне производње крава (0.155-0.256 kg/дан код високо продуктивних; 0.319-0.460 kg/дан код ниско продуктивних). Може се закључити да одговор првотелки Холштајн крава са фарми у Источној Хрватској на услове топлотног стреса зависи од нивоа њихове дневне производње.

Кључне ријечи: Холштајн првотелке, топлотни стрес, температурно-хумидни индекс, ниво дневне производње, источна Хрватска.

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