# Persistence of heat stress effect in dairy cows

**Gantner, Vesna; Bobić, Tina; Potočnik, Klemen; Gregić, Maja; Kučević, Denis**

ORIGINAL SCIENTIFIC PAPER | UDK: 637.112 | DOI: 10.15567/MLJEKARSTVO.2019.0103
RECEIVED: 20.08.2018. | ACCEPTED: 21.11.2018.

# *Persistence of heat stress effect in dairy cows*

*Vesna Gantner[1]*, Tina Bobić[1], Klemen Potočnik[2], Maja Gregić[1], Denis Kučević[3]*

[1]University of J. J. Strossmayer in Osijek, Faculty of Agriculture in Osijek, Vladimira Preloga 1, 31000 Osijek, Croatia
[2]University of Ljubljana, Biotechnical faculty, Department of Animal Science, Groblje 3, Domžale, Slovenia
[3]University of Novi Sad, Faculty of Agriculture, Trg D. Obradovića 8, 21000 Novi Sad, Serbia
*Corresponding author: E-mail: vgantner@pfos.hr

## *Abstract*

In order to determine the persistence of heat stress effect in dairy cows regarding the breed, parity and susceptibility to heat stress, over 1.9 million of test-day records from Holstein and Simmental cows reared in Croatia were used. The persistence of heat stress effect in the subsequent milk recordings was determined in cows that had significant decrease of daily milk yield at different THI threshold value (65, 70, 75, 80, and 85). The obtained results indicate that cows heat stressed at lower THI threshold value had higher proportional drop of daily milk yield in subsequent milk recordings. Also, primiparous and Simmentals experienced higher proportional drop when compared to multiparous and Holsteins. The negative effect of heat stress on daily milk contents that existed in all cows was more pronounced in the 2nd subsequent milk recording. The determined increase of somatic cell count in more heat stress sensitive Holsteins (THI in 65, 70, 75) indicates that Holstein cows, in terms of heat stress, also become more susceptible to mastitis. Finally, the lower was the THI threshold value, the stronger and more persistent was the heat stress effect. Considering the quite probable increase of the frequency of heat stress days, it is necessary to develop an adequate strategy for dairy farming. Aiming the accurate answer to the problem of heat stress in this region, it is necessary to conduct further research on genetic evaluation.

***Key words:*** **heat stress, persistence, dairy Simmentals, Holsteins, daily milk traits**

## *Introduction*

There is a growing demand for high production per cow in the current dairy cattle production. This production takes place in an environment that is suddenly changing to cows less comfort zone. According to the forecasts (IPCC, 2007), the climate also changes without a doubt, which will dramatically affect the animal production worldwide. According to Battisti and Naylor (2009), by the year 2050, most of the world will be exposed to median temperatures in the summer that will be higher than the highest recorded temperatures. Moreover, Reiczigel et al. (2009) indicated an increase of heat stress days/year (temperature-humidity index, THI>68) in Hungary from 5 to 17 over a period of 30 years. Discussing the global warming scenarios, Gauly et al. (2013) warned that the heat stress of high-producing dairy cows will cause a growing concern among the European milk producers. Segnalini et al. (2013) emphasized the need for adequate adaptation strategies development so that the negative effects of warming in farm animals in the Mediterranean basin could be reduced. According to Dunn et al. (2014), by 2100, there will be an increase in days exceeding the THI threshold value in the southern parts of the UK from an average 1-2 per year to over 20 per year. GIRA (Consultancy and Research Prospective and Strategie, 2012) has performed an analysis of Regional movements in the EU Milk Production and has predicted that European regions with intensive farming will be replaced by regions with less intensive farming around the Atlantic and with more land suitable for pasture (resulting in lower production costs). According to Hansen (2013), the increase of production makes cows more susceptible to heat stress, which means that heat stress will become an acute problem regardless of climate changes. Modern dairy cows, which are characterised by high levels of productivity, lose the ability to regulate their body temperature at air temperatures as low as 25-29 °C. The studies of Bohmanova (2006) and Collier et al. (2006) indicated that heat stress affects high-producing cows much more than low-producing ones. Kadzere et al. (2002) stated that the intensive genetic selection for milk production has changed the thermoregulation physiology of dairy cattle. The high-producing cows have larger frames and larger gastrointestinal tracts that enable them to digest more feed. This creates more metabolic heat and reduces the ability of cows to regulate normal temperature at heat stress conditions. According to Kadzere et al. (2002), the thermoneutrality shifts to lower temperatures due to the increase of milk yield, feed intake and metabolic heat. Also, Berman (2005) indicated that the increase in the daily milk yield from 35 to 45 kg/d results in a higher sensitivity to thermal stress and reduces the threshold temperature for intermediate heat stress by 5 °C. In dairy cows, the dry matter intake, the milk production (West et al., 1999; Casa and Ravelo, 2003) and the reproductive performances (Bohmanova et al., 2007; Ravagnolo et al., 2000) are reduced due to heat stress. In addition, heat stress affects milk composition, somatic cell counts (SCC) and mastitis frequencies (Bouraoui et al., 2002; Collier et al., 2012; Correa-Calderon et al., 2004; Gantner et al., 2011, 2017; Ravagnolo et al., 2000; St-Pierre et al., 2003; West 2003; Hammami et al., 2013; Smith et al., 2013). The heat stress condition also leads to considerable loss of profit, e.g. between $897 million and $1,500 million per year in the USA (St-Pierre et al. 2003). There are many ways to measure heat stress although the temperature-humidity index (THI) is the most common one when it comes to dairy cattle. THI includes ambient temperature and relative humidity and is a useful and simple method of assessing the risk of heat stress (Kibler 1964). According to Du Preez et al. (1990a, b), heat stress affects milk production and feed intake when THI values exceed 72. Bouraoui et al. (2002) set the threshold at 69, while Bernabucci et al. (2010) and Collier et al. (2012) set in at 68. Vitali et al. (2009) warned of the increased risk of cows' death when THI reaches 80. In the Croatian environment, a considerable decrease of daily milk traits (yield and contents) was also detected with the highest decline during summer periods in the Eastern and Mediterranean Croatia (Gantner et al., 2011). Is there an effective way to reduce the impact of heat stress at Croatian dairy farms? There are many methods to achieve that goal, such as shading, cooling and nutrition (Valtorta et al., 1997; Kadzere et al., 2002; West, 2003). Also, a selection aiming at heat stress resistance could be a successful long-term method (Bohmanova, 2006). Ravagnolo et al. (2000) detected the antagonistic relationship between the production of cows and heat tolerance. This relationship implies the deteriorate effect that the selection on productivity has on the resistance of cows to heat stress. Some other studies (Ravagnolo and Misztal, 2002a, b; Freitas et al., 2006; Aguilar et al., 2009) indicated the unfavourable genetic relationship between the THI and productive and reproductive traits. However, the selection on production can be successful as the example of the high-producing Holsteins in Israel illustrates (Aharoni et al., 1999). The focus of most research into heat stress has been on Holsteins, while only several studies have compared milk production of

Jersey and Holstein breeds in terms of heat stress (Harris et al., 1960; Collier et al., 1981; Smith et al., 2013). Our earlier research (Gantner et al., 2017), the purpose of which was to determine THI threshold value for daily milk traits (yield, fat and protein content) of dairy cattle (Holsteins and Simmentals), showed a higher resistance to heat stress in Simmentals than Holsteins.

The aim of this research was to determine the persistence of heat stress effect in dairy cows in respect to the breed (Simmental, Holstein), parity (I, II, III) and susceptibility to heat stress.

## Material and methods

Individual test-day records of dairy Simmental and Holstein cows collected during the regular milk recording performed by an alternative milk recording method (AT4/BT4) in the period from January 2005 to December 2012 in Croatia were used for the statistical analysis. Monthly, at each recording, milk yields were measured during the evening or morning milking. Additionally, at each milk recording, ambient temperature and relative humidity were recorded. Daily temperature-humidity index (THI) was calculated using the equation by Kibler (1964):

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

Where *Ta* is the 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 the first calving in (< 21 and > 36 months), missing or parity > 7 (Simmentals) / 6 (Holsteins) /, and missing or nonsense *Ta* and *RH* value were deleted from the dataset. Regarding the parity, cows were divided into 3 groups: I, II and III. Also, only cows with a minimum of 3 test day per parity were taken into analysis. Data, provided by the Croatian Agricultural Agency, after logical control consisted of 831,785 test-day records from 66,740 Holsteins reared on 5,536 farms and 1,109,171 test-day records from 83,086 Simmentals reared on 8,670 farms in Croatia. Variability of daily milk traits (daily milk yield, DMY; daily fat content, DFC; daily protein content, DPC; somatic cell count, SCC) regarding breed (Simmental, Holstein) and parity (I, II, III) is presented in Table 1.

**TABLE 1.** Descriptive statistics of daily milk traits (milk yield, kg, DMY; fat content, %, DFC; protein content, %, DPC; somatic cell count, 000, SCC) per parity and breed

| Trait | Parity | Simmental | | | | Holstein | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | mean | SD | CV | n | mean | SD | CV | n |
| DMY kg | I | 15.58 | 5.09 | 32.64 | 273420 | 21.18 | 7.09 | 33.47 | 293351 |
| | II | 16.60 | 6.06 | 36.52 | 250452 | 23.46 | 9.17 | 39.01 | 236523 |
| | III | 16.56 | 6.08 | 36.70 | 555680 | 23.19 | 9.33 | 40.21 | 288446 |
| DFC % | I | 4.15 | 0.84 | 20.13 | 272360 | 4.06 | 0.91 | 22.38 | 289709 |
| | II | 4.17 | 0.88 | 21.22 | 248977 | 4.13 | 0.96 | 23.37 | 232189 |
| | III | 4.10 | 0.90 | 21.99 | 549623 | 4.12 | 0.97 | 23.54 | 283065 |
| DPC % | I | 3.39 | 0.42 | 12.41 | 274240 | 3.30 | 0.40 | 12.17 | 291597 |
| | II | 3.48 | 0.44 | 12.79 | 250912 | 3.35 | 0.43 | 12.95 | 233845 |
| | III | 3.39 | 0.43 | 12.75 | 554961 | 3.30 | 0.43 | 13.06 | 285138 |
| SCC 000 | I | 15.88 | 1.76 | 11.05 | 281072 | 16.19 | 1.71 | 10.59 | 298075 |
| | II | 16.16 | 1.81 | 11.20 | 256328 | 16.47 | 1.77 | 10.72 | 237325 |
| | III | 16.53 | 1.81 | 10.93 | 564538 | 16.83 | 1.74 | 10.32 | 287739 |

The variation in daily milk traits due to heat stress was tested by least square analyses of variance for each given THI value (65, 70, 75, 80, 85) in regard to the breed (Simmental, Holstein) separately for each parity class (I, II, III) and using the PROC MIXED procedure in SAS (SAS Institute Inc., 2000). Following mixed model was used:

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

Where $y_{ijklm}$ = estimated daily milk trait;
$\mu$ = 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 = 1/2005 to 12/2012);
$A_k$ = fixed effect of age at calving class k (k = 21 to 36 month) *only for 1st parity,
$R_l$ = fixed effect of region k (l = Croatian counties),
$T_m$ = fixed effect of THI class (m = 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 differences between the THI classes was tested by the t-test. Only cows that were producing in heat stress conditions (test-day records with THI = 1) with daily milk yield lower than LS-means + STDERR when THI = 1 were included in the further analyses. The daily milk trait measured on the recording day when heat stress occurred (for each given THI value (65, 70, 75, 80, 85)) was used as the reference level. The proportional drop in the daily milk traits was determined in the 1st (test-day milk traits measured within 35 days) and 2nd (test-day milk traits measured between 35 and 70 days) milk recording after heat stress. Also, only subsequent test-day records with THI = 0 were taken into account. The persistence of the effect of heat stress on daily milk traits were analysed separately for each breed and parity.

## Results and discussion

The maximum values of THI (temperature-humidity index) measured during milk recording of dairy cows in the period from January till December in accordance with the recording year (2005 - 2012) are presented in Table 2 (Simmentals) and Table 3 (Holsteins). Microclimate conditions during milk recording of both breeds were quite similar. As it is presented in Tables 2 and 3, the unfavourable microclimate appeared even in the winter (Dec, Jan, and Feb) period. Furthermore, spring (Mar, Apr, and May) and autumn (Sep, Oct, and Nov) periods were characterized by the occurrence of very high values of maximum THI (> 75). The appearance of extremely high maximum values of THI (> 90) determined in the summer (Jun, Jul, and Aug) period indicates that both breeds were under extremely unfavourable microclimate conditions.

**TABLE 2.** Maximum values of THI (temperature-humidity index) measured during milk recording of Simmental cows in the period from January till December with regard to the recording year

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 53 | 67 | 80 | 81 | 83 | 91 | 97 | 94 | 86 | 84 | 79 | 67 |
| 2006 | 67 | 68 | 83 | 82 | 84 | 99 | 96 | 96 | 84 | 83 | 81 | 67 |
| 2007 | 67 | 67 | 79 | 80 | 83 | 101 | 99 | 95 | 83 | 82 | 82 | 67 |
| 2008 | 67 | 67 | 81 | 80 | 83 | 97 | 97 | 93 | 85 | 81 | 82 | 68 |
| 2009 | 67 | 67 | 79 | 81 | 83 | 90 | 97 | 94 | 83 | 80 | 80 | 67 |
| 2010 | 67 | 67 | 82 | 82 | 82 | 93 | 97 | 96 | 81 | 83 | 81 | 68 |
| 2011 | 67 | 67 | 80 | 82 | 84 | 100 | 101 | 100 | 85 | 81 | 82 | 68 |
| 2012 | 67 | 67 | 82 | 82 | 83 | 94 | 98 | 100 | 84 | 84 | 77 | 67 |

**TABLE 3.** Maximum values of THI (temperature-humidity index) measured during milk recording of Holstein cows in the period from January till December in accordance to the recording year

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 53 | 65 | 73 | 80 | 83 | 90 | 94 | 99 | 86 | 82 | 78 | 67 |
| 2006 | 67 | 67 | 83 | 82 | 83 | 99 | 96 | 99 | 84 | 82 | 80 | 67 |
| 2007 | 67 | 67 | 76 | 81 | 83 | 101 | 99 | 99 | 83 | 81 | 77 | 67 |
| 2008 | 67 | 67 | 73 | 80 | 83 | 95 | 97 | 99 | 84 | 81 | 81 | 68 |
| 2009 | 67 | 67 | 79 | 80 | 83 | 90 | 97 | 99 | 82 | 80 | 79 | 67 |
| 2010 | 67 | 67 | 82 | 81 | 84 | 94 | 97 | 99 | 86 | 82 | 82 | 67 |
| 2011 | 67 | 67 | 80 | 82 | 84 | 100 | 101 | 99 | 84 | 83 | 79 | 67 |
| 2012 | 67 | 67 | 82 | 79 | 83 | 92 | 98 | 99 | 84 | 81 | 79 | 67 |

Our earlier research (Gantner et al., 2011) showed high frequency of days with THI > 72 in the late spring and summer period even when the mean daily THI values were analysed. Furthermore, the obtained results indicated that the heat stress condition may occur even in periods characterised by lower ambient temperatures since problems could also be caused by a high relative humidity. For instance, Du Preez et al. (1990a) studied the heat stress in dairy cattle under South African conditions, and observed that milk production was affected by heat stress at THI values higher than 72, which corresponded to 22 °C at 100 % humidity, 25 °C at 50 % humidity, or 28 °C at 20 % humidity. The correlation of temperature and humidity was also studied by Bianca (1965) who reported that at a temperature of 29 °C and 40 % relative humidity the milk yield of Holstein, Jersey and Brown Swiss cows was at 97, 93, and 98 % of the normal production, but when the relative humidity increased to 90 %, the yields dropped to 69, 75, and 83 % of the normal production. The THI threshold values depend on a variety of factors, such as the production level, parity, breed, region (Kadzere et al., 2002; Bohmanova, 2006; Collier et al., 2006; Hansen, 2013). For example, Du Preez et al. (1990a, b) determined that milk dairy cows were affected by heat stress at THI values higher than 72. Bouraoui et al. (2002) set the threshold at 65-69, while Bernabucci et al. (2010) as well as Collier et al. (2012) at 68.

Taking into consideration that different cows respond differently, the aim of this study was to determine the persistence of heat stress in the subsequent milk recordings depending on THI value at which a statistically significant decrease of daily milk yield occurred. The proportional drop in the daily milk traits in subsequent milk recordings after heat stress in accordance with the breed and parity of cows that had statistically significant decrease of daily milk yield at different THI values (65, 70, 75, 80, and 85) is presented in Tables 4-8.

In the first parity Simmentals, that experienced statistically significant decrease of daily milk yield at THI≥65 (Table 4), in the 1$^{st}$ subsequent milk recording the daily milk yield dropped for 27.68 %, while in the 2$^{nd}$ subsequent milk recording the proportional drop in milk production was even higher (32.79 %). The higher drop in the second milk recording was also observed for daily fat and protein content (3.70 % and 0.42 % respectively). The proportional drop of the somatic cell count (SCC) in subsequent milk recordings was also observed. Furthermore, a higher proportional drop in the daily milk yield and contents in the second milk recording were also observed in multiparous Simmentals. Compared to Simmentals, Holsteins showed similar trends but a lower proportional drop of daily milk yield in subsequent milk recordings, with the exception of SCC which increased in subsequent recordings. The highest increase occurred in the first parity Holsteins in the 2$^{nd}$ milk recording after the heat stress (for 0.49 %).

**TABLE 4.** Proportional drop in daily milk traits in subsequent milk recordings after heat stress in accordance to the breed (Simmental, Holstein) and parity (I, II, III) when THI≥65

| Parity | 1st milk recording after heat stress | | | | 2nd milk recording after heat stress | | | |
|---|---|---|---|---|---|---|---|---|
| | DMY | DFC | DPC | SCC (000) | DMY | DFC | DPC | SCC (000) |
| | Simmental | | | | | | | |
| I | 27.68 | 2.65 | 0.29 | 0.13 | 32.79 | 3.70 | 0.42 | 0.14 |
| II | 26.97 | 3.15 | -1.08 | -0.25 | 30.01 | 3.60 | -1.62 | -0.18 |
| III | 22.11 | 3.18 | 0.75 | 0.20 | 26.13 | 4.37 | 0.98 | 0.25 |
| | Holstein | | | | | | | |
| I | 24.64 | 2.74 | 0.73 | -0.48 | 31.20 | 3.31 | 0.85 | -0.49 |
| II | 19.30 | 3.14 | 1.03 | -0.40 | 24.57 | 4.02 | 1.28 | -0.34 |
| III | 19.30 | 3.14 | 1.03 | -0.39 | 24.56 | 4.02 | 1.28 | -0.34 |

DMY - daily milk yield (%); DFC - daily fat content (%); DPC - daily protein content (%); SCC - somatic cell count (%)

The heat stress effect in cows that experience statistically significant decrease of daily milk yield at THI≥70 (Table 5) existed in the 1st and 2nd subsequent milk recordings. Primiparous cows had higher proportional drop in daily milk yield compared to multiparous. Also, the proportional drop of daily milk yield and daily contents increased in the 2nd milk recording in all cows. Furthermore, Simmentals experienced a higher proportional drop in the daily milk yield and contents compared to Holsteins. Regarding the SCC, Holsteins unlike Simmentals experience an increase in the subsequent milk recordings with the highest increase in the 2nd subsequent milk recording in first parity cows.

**TABLE 5.** Proportional drop in daily milk traits in subsequent milk recordings after heat stress in accordance to the breed (Simmental, Holstein) and parity (I, II, III) when THI≥70

| Parity | 1st milk recording after heat stress | | | | 2nd milk recording after heat stress | | | |
|---|---|---|---|---|---|---|---|---|
| | DMY | DFC | DPC | SCC (000) | DMY | DFC | DPC | SCC (000) |
| | Simmental | | | | | | | |
| I | 25.24 | 2.97 | 1.02 | 0.30 | 32.51 | 4.61 | 1.53 | 0.39 |
| II | 19.19 | 3.46 | 1.42 | 0.42 | 24.85 | 5.38 | 2.15 | 0.48 |
| III | 19.61 | 3.47 | 1.39 | 0.41 | 25.41 | 5.32 | 2.10 | 0.46 |
| | Holstein | | | | | | | |
| I | 22.91 | 3.02 | 1.26 | -0.27 | 30.57 | 4.31 | 1.59 | -0.34 |
| II | 17.68 | 3.29 | 1.51 | -0.23 | 23.81 | 4.85 | 1.98 | -0.22 |
| III | 17.56 | 3.30 | 1.52 | -0.21 | 23.67 | 4.86 | 1.98 | -0.21 |

DMY - daily milk yield (%); DFC - daily fat content (%); DPC - daily protein content (%); SCC - somatic cell count (%)

The cows (Simmentals and Holsteins) that experience statistically significant decrease of the daily milk yield at THI≥75 (Table 6) had similar trends but a lower proportional drop in the daily milk yield compared to less heat stress resistant cows (Table 4 and 5). A proportional drop in daily milk contents increased in the 2nd compared to the 1st subsequent control in all cows regardless of the breed and parity. Also, in this group of cows Holsteins experienced a small increase of SCC in both subsequent milk recording.

**TABLE 6.** Proportional drop in daily milk traits in subsequent milk recordings after heat stress in accordance to the breed (Simmental, Holstein) and parity (I, II, III) when THI≥75

| Parity | 1st milk recording after heat stress | | | | 2nd milk recording after heat stress | | | |
|---|---|---|---|---|---|---|---|---|
| | DMY | DFC | DPC | SCC (000) | DMY | DFC | DPC | SCC (000) |
| | Simmental | | | | | | | |
| I | 22.53 | 3.34 | 1.43 | 0.60 | 30.49 | 5.52 | 2.51 | 0.77 |
| II | 16.64 | 3.60 | 1.84 | 0.58 | 22.71 | 6.12 | 3.07 | 0.74 |
| III | 17.06 | 3.57 | 1.79 | 0.59 | 23.32 | 6.09 | 3.02 | 0.74 |
| | Holstein | | | | | | | |
| I | 20.12 | 2.57 | 2.25 | -0.18 | 27.94 | 4.78 | 2.83 | -0.22 |
| II | 15.04 | 2.86 | 2.49 | -0.07 | 20.95 | 5.47 | 3.30 | -0.05 |
| III | 15.03 | 2.86 | 2.49 | -0.07 | 20.95 | 5.47 | 3.30 | -0.05 |

DMY - daily milk yield (%); DFC - daily fat content (%); DPC - daily protein content (%); SCC - somatic cell count (%)

Similar to the previous group, in all Simmentals that experienced statistically significant decrease of the daily milk yield at THI≥80 (Table 7), the heat stress effect also existed in both subsequent milk recordings, with lower proportional drop in multiparous Simmentals and in the first subsequent control. A drop of the daily milk yield persisted in subsequent milk recordings was observed in Holsteins as well, but in a lower amount compared to the less resistant groups (Table 4, 5, and 6). The trend of the drop increase of daily contents in the 2nd subsequent control was observed in both breeds. A small increase of the SCC in the 2nd milk recording was observed in all Holsteins.

In the group of cows that experience statistically significant decrease of the daily milk yield at THI≥85 (Table 8), the trend of higher proportional drop of daily milk yield contents in the 2nd subsequent milk recording and in primiparous cows was observed in both breeds. A small decrease of SCC (less than 1 %) was determined in all cows in both subsequent milk recordings.

**TABLE 7.** Proportional drop in daily milk traits in subsequent milk recordings after heat stress in accordance to the breed (Simmental, Holstein) and parity (I, II, III) when THI≥80

| | 1st milk recording after heat stress | | | | 2nd milk recording after heat stress | | | |
|---|---|---|---|---|---|---|---|---|
| Parity | DMY | DFC | DPC | SCC (000) | DMY | DFC | DPC | SCC (000) |
| | Simmental | | | | | | | |
| I | 20.97 | 4.23 | 2.37 | 0.95 | 30.16 | 5.49 | 3.30 | 0.97 |
| II | 15.28 | 4.34 | 2.70 | 0.83 | 22.26 | 6.12 | 3.82 | 0.95 |
| III | 15.55 | 4.31 | 2.66 | 0.82 | 22.77 | 6.12 | 3.78 | 0.95 |
| | Holstein | | | | | | | |
| I | 20.55 | 2.23 | 2.12 | -0.03 | 26.59 | 5.00 | 3.77 | -0.34 |
| II | 15.81 | 2.54 | 2.17 | 0.001 | 20.43 | 5.46 | 4.15 | -0.15 |
| III | 16.03 | 2.61 | 2.16 | 0.00 | 20.79 | 5.46 | 4.12 | -0.12 |

DMY - daily milk yield (%); DFC - daily fat content (%); DPC - daily protein content (%); SCC - somatic cell count (%)

**TABLE 8.** Proportional drop in daily milk traits in subsequent milk recordings after heat stress in accordance to the breed (Simmental, Holstein) and parity (I, II, III) when THI≥85

| Parity | 1st milk recording after heat stress | | | | 2nd milk recording after heat stress | | | |
|---|---|---|---|---|---|---|---|---|
| | DMY | DFC | DPC | SCC (000) | DMY | DFC | DPC | SCC (000) |
| | Simmental | | | | | | | |
| I | 19.19 | 4.27 | 2.14 | 0.79 | 26.03 | 6.40 | 3.35 | 0.96 |
| II | 14.34 | 4.30 | 2.67 | 0.64 | 19.74 | 7.01 | 4.03 | 0.79 |
| III | 14.52 | 4.43 | 2.63 | 0.70 | 20.21 | 7.16 | 4.07 | 0.83 |
| | Holstein | | | | | | | |
| I | 18.03 | 2.23 | 2.51 | 0.72 | 23.08 | 5.47 | 4.49 | 0.53 |
| II | 14.19 | 2.18 | 2.46 | 0.68 | 19.05 | 6.08 | 4.88 | 0.58 |
| III | 13.16 | 2.29 | 2.52 | 0.66 | 17.88 | 6.15 | 4.78 | 0.72 |

DMY - daily milk yield (%); DFC - daily fat content (%); DPC - daily protein content (%); SCC - somatic cell count (%)

The analyses of daily milk yield showed that the proportional drop in subsequent milk recordings was higher at a lower THI threshold value. Also, the highest proportional drop of daily milk yield was determined in primiparous with a tendency of drop increase in the 2nd subsequent milk recording. On the other hand, multiparous had a lower proportional drop of daily milk yield with a same tendency to increase the drop in the 2nd subsequent milk recording. Furthermore, Holsteins experienced similar trends but lower proportional drop in daily milk yield. These results indicated that the negative effect of heat stress was more pronounced in primiparous cows. Also, Simmentals were more susceptible to heat stress. Furthermore, the lower was the THI threshold value, the stronger and more persistent was the heat stress effect.

A lot of research has been carried out on the negative effect of heat stress on the daily milk yield of dairy cattle. For example, Casa and Ravelo (2003) determined that heat stress during the warmer months in Argentina caused a fall 6 % to 9 % (depending on the region) in production, in relation to the normal production level of 22 L/cow/day. According to Bernabucci et al. (2010) and Collier et al. (2012), there was a decrease at THI=68, while Bouraoui et al. (2002) observed a decrease in milk production of dairy cows in the Mediterranean climate at THI≥69. Bouraoui et al. (2002) detected a decrease of milk yield by 0.41 kg per cow per day for each point increase in the value of THI above 69. Du Preez et al. (1990a, b) found out that dairy cows in South African conditions were affected by heat stress at THI values above 72. According to the same authors, the amount of the milk yield drop for Holstein cows during the summer period when compared to the winter period was about 10 % to 40 % (Du Preez et al., 1990b). An U.S. research detected different threshold values regarding the region, for example 72 in Georgia, and 74 in Arizona (Bohmanova et al., 2007). The difference between the detected threshold values could be related to factors such as better adapted cows, farm management or special housing characteristics. For example, Lambertz et al. (2014) detected that housing systems significantly influenced the drop of fat corrected milk (FCM) in Holstein cows while the highest drop was determined in the classic indoor system. The conclusion was that heat stress resulted in a decreased milk yield, fat, and protein contents, and the increased somatic cell score (SCS).

Several studies have been conducted on the differences in response to heat stress among breeds. For instance, Bianca (1965) detected a higher drop of milk production in Holstein cows compared to other breeds like the Jersey and the Brown Swiss. Collier et al. (1981) also suggested that Jersey cows may be more heat tolerant than Holstein cows in terms of milk yield production. According to Smith et al. (2013), there is an increase in milk production of Jersey cows during heat stress. The same study detected a decrease of milk production of Holstein cows during heat stress. Accordingly, Jersey cows used in the study could prove to be more heat tolerant than Holsteins. Johnson et al. (1962) studied the persistence of heat stress effect too. They discovered that once the hot season was over, the productivity of the high-producing cows did not go back to normal since the energy deficite could not be fully restored.

The analysis of daily milk contents, fat and protein, showed a higher proportional drop in daily fat (2.54 % - 4.43 % at the 1st subsequent milk recording; 3.30 % - 7.16 % at the 2nd subsequent milk recording) than protein (0.29 % - 2.70 % at the 1st subsequent milk recording; 0.42 % - 4.88 % at the 2nd subsequent milk recording) content. Also, the amount of the proportional drop increased in the 2nd compared to the 1st subsequent milk recording in both breeds as well as in all parities.

Other studies also showed a decrease of daily milk contents. Bouraoui et al. (2002) detected a decrease of the daily fat (3.24 vs. 3.58 %) content and a decrease of the daily fat (0.68 vs. 0.48) yields during heat stress and the normal condition that was in summer compared to spring. According to the same study, there was a decrease of daily protein (2.88 vs. 2.96 %) content as well as a decrease of daily protein (0.56 vs. 0.43) yields during the summer compared to the spring period. Rodrigez et al. (1985) and Kadzere et al. (2002) determined the fat and protein percentage decline that was associated with heat stress environments while showing that the percentage of milk fat dropped by 39.7 % and that milk protein percentage dropped by 16.9 %. Lambertz et al. (2014) detected a statistically noticeable drop of the daily fat and the protein content with the increase of THI values in indoor Holstein cows. On the other hand, according to Knapp and Grummer (1991), there was no noticeable drop in the fat content for cows under heat stress. The same authors explained a decrease in proteins with the increase in the maximum daily temperature by a decreased energy and dry matter intake.

The analyses of the somatic cell count showed a small decrease of SCC (less than 1 %) in subsequent milk recordings in Simmental cows. Conversely, Holsteins that experience decrease of daily milk yield at lower THI threshold values (65, 70, 75) tend to a small increase in the SCC value in both subsequent milk recordings. At a higher THI threshold value (80) primiparous Holsteins increased SCC value at the 1st subsequent control, while all Holsteins regardless of the parity increased the SCC value at the 2nd subsequent milk recording. At the highest THI threshold value (85) all Holsteins at both subsequent milk recordings decreased the SCC value. This increase of the somatic cell count could indicate a higher susceptibility of Holsteins to mastitis as a consequence of heat stress conditions.

Bouraoui et al. (2002) also detected the negative effects of heat stress with the increasing SCC from spring to summer. According to Lambertz et al. (2014), there was a correlation between the increasing THI values and the increasing somatic cell score (SCS) in Holsteins, observed in four different housing systems. Based on the analysis of heat stress effects in Holsteins and Jersey breeds in terms of milk and component yields and SCS, Smith et al. (2013) concluded that Jersey cows seemed to be more heat tolerant than Holsteins.

## Conclusions

The results of the conducted research indicate that the proportional drop of daily milk yield in the subsequent milk recordings was higher in cows heat stressed at lower THI threshold value. Also, the highest proportional drop in the daily milk yield was determined in primiparous cows, while multiparous had a lower proportional drop but the same tendency to increase the drop in the 2nd subsequent milk recording. Holsteins experienced similar trends as Simmentals but lower proportional drop in the daily milk yield. The negative effect of heat stress on daily milk contents that was observed in all cows was more pronounced in the 2nd subsequent milk recording. A discovered small increase in the somatic cell count in more heat stress sensitive Holsteins (THI in 65, 70, 75) indicates that Holstein cows also become more susceptible to mastitis under terms of heat stress. The obtained results indicate that the negative effect of heat stress was more pronounced in primiparous cows and in Simmental breed. Finally, the lower was the THI threshold value, the stronger and more persistent was the heat stress effect.

Considering a quite probable increase of the frequency of heat stress days, it is necessary to develop an adequate strategy for dairy farming. Aiming the accurate answer to the problem of heat stress in this region, it is necessary to conduct further research on genetic evaluation.

# *Perzistencija utjecaja toplinskog stresa u mliječnih krava*


## Sažetak

U cilju utvrđivanja perzistencije utjecaja toplinskog stresa u mliječnih krava i to u ovisnosti o pasmini, redoslijedu laktacije te osjetljivosti na toplinski stres analizirano je preko 1,9 milijuna zapisa na kontrolni dan mliječnih krava uzgajanih u Hrvatskoj. Perzistencija utjecaja toplinskog stresa pri sukcesivnim kontrolama mliječnosti utvrđivana je u krava koje su imale signifikantan pad dnevne količine mlijeka pri različitim graničnim vrijednostima THI-a (65, 70, 75, 80, i 85). Utvrđeni rezultati ukazuju da krave koje su doživjele toplinski stres pri nižim vrijednostima THI-a imaju veći pad u dnevnoj proizvodnji mlijeka u narednim kontrolama. Nadalje, prvotelke te krave simentalske pasmine imale su relativno veći pad proizvodnje komparabilno sa grlima u višim laktacijama te holstein pasminom. Negativni utjecaj toplinskog stresa na dnevni sadržaj mlijeka utvrđen je u svih krava te je bio izraženiji u drugoj sukcesivnoj kontroli komparabilno s prvom. Utvrđeni porast broja somatskih stanica u holstein pasmine osjetljivije na toplinski stres (THI 65, 70, 75) indicira da holstein krave u uvjetima toplinskog stresa postaju podložnije pojavi mastitisa. U konačnici, što je niža THI *threshold* vrijednost, to je izraženiji i dugotrajniji utjecaj toplinskog stresa. Imajući na umu vrlo vjerojatne promjene klime u smjeru povećanja frekvencije dana sa toplinskim stresom, nužan je razvoj adekvatnih strategija za mliječno govedarstvo. U cilju pronalaska rješenja za problem toplinskog stresa u ovoj regiji nužna je provedba daljnjih istraživanja u cilju genetske evaluacije na rezistentnost na toplinski stres.


***Ključne riječi:*** **toplinski stres, perzistencija, mliječne simentalke, holsteinke, dnevne karakteristike mlijeka**

# *References*


1. Aguilar, I., Misztal, I., Tsuruta, S. (2009): Genetic components of heat stress for dairy cattle with multiple lactation. *Journal of Dairy Science* 92, 5702-5711. https://doi.org/10.3168/jds.2008-1928
2. Aharoni, Y., Brosh, A., Ezra, E. (1999): Effect of heat load and photoperiod on milk yield and composition in three dairy herds in Israel. *Animal Science* 69, 37-47. https://doi.org/10.1017/S1357729800051079
3. Battisti, D.S., Naylor, R.L. (2009): Historical warnings of future food insecurity with unprecedented seasonal heat. *Science*; 323, 240-244. https://doi.org/10.1126/science.1164363
4. Berman, A. (2005): Estimates of heat stress relief needs for Holstein dairy cows. *Journal of Animal Science* 83, 1377-1384. https://doi.org/10.2527/2005.8361377x
5. Bernabucci, U., Lacetera, N., Baumgard, L.H., Rhoads, R.P., Ronchi, B., Nardone, A. (2010): Metabolic and hormonal acclimation to heat stress in domestic ruminants. *Animal*, 4, 1167-1183. https://doi.org/10.1017/S175173111000090X
6. Bianca, W. (1965): Reviews of the progress of dairy science. Section A. Physiology. Cattle in a hot environment. *Journal of Dairy Research* 32, 291-345. https://doi.org/10.1017/S0022029900018665
7. Bohmanova, J. (2006): Studies on genetics of heat stress in US Holsteins. PhD thesis, University of Georgia, Athens, GA, USA.
8. Bohmanova, J., Misztal, I., Cole, J.B. (2007): Temperature-humidity indices as indicators of milk production losses due to heat stress. *Journal of Dairy Science* 90, 1947-1956. https://doi.org/10.3168/jds.2006-513
9. Bouraoui, R., Lahmar, M., Majdoub, A., Djemali, M., Belyea, R. (2002): The relationship of temperature humidity-index with milk production of dairy cows in a Mediterranean climate. *Animal Research* 51, 479-491. https://doi.org/10.1051/animres:2002036
10. Casa, A.C., Ravelo, A.C. (2003): Assessing temperature and humidity conditions for dairy cattle in Cordoba, Argentina. *International Journal of Biometeorology* 48, 6-9. https://doi.org/10.1007/s00484-003-0179-x
11. Collier, R.J., Eley, R.M., Sharma, A.K., Pereira R.M, Buffington, D.E. (1981): Shade management in subtropical environment for milk yield and composition in Holstein and Jersey cows. *Journal of Dairy Science* 64, 844-849. https://doi.org/10.3168/jds.S0022-0302(81)82656-2
12. Collier, R.J., Dahl, G.E., van Baale, M.J. (2006): Major advances associated with environmental effects on dairy cattle. *Journal of Dairy Science* 89, 1244-1253. https://doi.org/10.3168/jds.S0022-0302(06)72193-2
13. Collier, R.J., Hall, L.W. (2012): Quantifying heat stress and its impact on metabolism and performance. Department of Animal Sciences. University of Arizona.

14. Correa-Calderon, A., Armstrong, D., Ray, D., de Nise, S., Enns, M., Howison, C. (2004): Thermoregulatory responses of Holstein and Brown Swiss heat-stressed dairy cows to two different cooling systems. *International Journal of Biometeorology* 48, 142-148. https://doi.org/10.1007/s00484-003-0194-y
15. Dunn, R.J.H., Mead, N.E., Willett, K.M., Parker, D.E. (2014): Analysis of heat stress in UK dairy cattle and impact on milk yields. *Environmental Research Letters* 9, 064006.
16. Du Preez, J.H., Giesecke, W.H., Hattingh, P.J. (1990a): Heat stress in dairy cattle and other livestock under Southern African conditions. I. Temperature-humidity index mean values during the four main seasons. *Onderstepoort Journal of Veterinary Research* 57, 77-86.
17. Du Preez, J.H., Hatting, P.J., Giesecke, W.H., Eisenberg, B.E. (1990b): Heat stress in dairy cattle and other livestock under Southern African conditions. III. Monthly temperature-humidity index mean values and their significance in the performance of dairy cattle. *Onderstepoort Journal of Veterinary Research* 57, 243-248.
18. Freitas, M., Misztal, I., Bohmanova, J., Torres, R. (2006): Regional differences in heat stress in US Holsteins. Proceedings 8th World Congress Genet. Appl. Livest. Prod. Commun. 01-11. Istituto Prociencia, Belo Horizonte, Brazil.
19. Gantner, V., Mijić, P., Kuterovac, K., Solić, D., Gantner, R. (2011): Temperature-humidity index values and their significance on the daily production of dairy cattle. *Mljekarstvo*, 61 (1), 56- 63.
20. Gantner, V., Bobić, T., Gantner, R., Gregić, M., Kuterovac, K., Novaković, J., Potočnik, K. (2017): Differences in response to heat stress due to production level and breed of dairy cows. *International Journal of Biometeorology* 61, 9; 1675-1685. https://doi.org/10.1007/s00484-017-1348-7
21. Gauly, M., Bollwein, H., Breves, G., Brügemann, K., Dänicke, S., Das, Demeler, J.G., Hansen, H., Isselstein, J., König, S., Lohölter, M., Martinsohn, M., Meyer, U., Potthoff, M., Sanker, C., Schröder, B., Wrage, N., Meibaum, B., von Samson-Himmelstjerna, G., Stinshoff, H., Wrenzycki, C. (2013): Future consequences and challenges for dairy cow production systems arising from climate change in Central Europe - A review. *Animal* 7, 843-859. https://doi.org/10.1017/S1751731112002352
22. GIRA - Consultancy and Research Prospective and Strategie (2012): World and EU dairy through 2016. http://ec.europa.eu/agriculture/milk/background/jm-2012-12-12/01-gira_en.pdf.
23. Hammami, H., Bormann, J., M'hamdi, N., Montaldo, H.H., Gengler, N. (2013): Evaluation of heat stress effects on production traits and somatic cell score of Holsteins in a temperate environment. *Journal of Dairy Science* 96: 1844-1855. https://doi.org/10.3168/jds.2012-5947
24. Hansen, P.J. (2013): Genetic Control of Heat Stress in Dairy Cattle. Proceedings 49th Florida Dairy Production Conference, Gainesville, April 10, 2013.
25. Harris, D.L., Shrode, R.R., Rupel, I.W., Leighton, R.E. (1960): A study of solar radiation as related to physiological and production responses of lactating Holstein and Jersey cows. *Journal of Dairy Science* 43, 1255-1262. https://doi.org/10.3168/jds.S0022-0302(60)90312-X
26. Intergovernmental Panel on Climate Change - IPCC: Climate Change 2007 (2007): The physical science basis. contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge/New York, NY, USA.
27. Johnson, H.D., Ragsdale, A.C., Berry, I.L., Shanklin, M.D. (1962): Effect of various temperature humidity combinations on milk production of Holstein cattle. *Research Bulletin* Missouri Agric. Exp. Station, 791.
28. Kadzere, C.T., Murphy, M.R., Silanikove, N., Maltz, E. (2002): Heat stress in lactating dairy cows: A Review. *Livestock of Production Science*, 77, 59-91. https://doi.org/10.1016/S0301-6226(01)00330-X
29. Kibler, H.H. (1964): Environmental physiology and shelter engineering. LXVII. Thermal effects of various temperature-humidity combinations on Holstein cattle as measured by eight physiological responses, *Research Bulletin* Missouri Agric. Exp. Station, 862.
30. Knapp, D.M., Grummer, R.R. (1991): Response of lactating dairy cows to fat supplementation during heat stress. *Journal of Dairy Science* 74, 2573-2579. https://doi.org/10.3168/jds.S0022-0302(91)78435-X
31. Lambertz, C., Sanker, C., Gauly, M. (2014): Climatic effects on milk production traits and somatic cell score in lactating Holstein-Friesian cows in different housing systems. American Dairy Science Association. *Journal of Dairy Science* 97 (1), 319-329. https://doi.org/10.3168/jds.2013-7217
32. Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S., Bernabucci, U. (2010): Effects of climate changes on animal production and sustainability of livestock systems. *Livestock Science* 130, 57-69. https://doi.org/10.1016/j.livsci.2010.02.011
33. Ravagnolo, O., Misztal, I., Hoogenboom, G. (2000): Genetic component of heat stress in dairy cattle, development of heat indeks function. *Journal of Dairy Science* 83, 2120-2125. https://doi.org/10.3168/jds.S0022-0302(00)75094-6
34. Ravagnolo, O., Misztal, I. (2000a): Studies on genetics of heat tolerance in dairy cattle with reduced weather information via cluster analysis. *Journal of Dairy Science* 85,1586-1589. https://doi.org/10.3168/jds.S0022-0302(02)74228-8
35. Ravagnolo, O., Misztal. I. (2000b): Effect of heat stress on nonreturn rate in Holstein cows: Genetic analysis. *Journal of Dairy Science* 85, 3092-3100. https://doi.org/10.3168/jds.S0022-0302(02)74396-8
36. Reiczigel, J., Solymosi, N., Könyves, L., Maróti-Agóts, A., Kern, A., Bartyik, J. (2009): Examination of heat stress caused milk production loss by the use of temperature-humidity indices. *Magy Allatorv*, 131, 137-144.
37. Rodriguez, L.W., Mekonnen, G., Wilcox, C.J., Martin, F.G., Krienk, W.A. (1985): Effects of relative humidity, maximum and minimum temperature, pregnancy and stage of lactation on milk composition and yield. *Journal of Dairy Science* 68, 973-978. https://doi.org/10.3168/jds.S0022-0302(85)80917-6
38. SAS User's Guide (2000): Version 8.2 Edition. SAS Institute Inc. Cary, NC.

39. Segnalini, M., Bernabucci, U., Vitali, A., Nardone, A., Lacetera, N. (2013): Temperature humidity index scenarios in the Mediterranean basin. *International Journal of Biometeorology* 57, 451-458. https://doi.org/10.1007/s00484-012-0571-5
40. Smith, D.L., Smith, T., Rude, B.J., Ward, S.H. (2013): Comparison of the effects of heat stress on milk and component yields and somatic cell score in Holstein and Jersey cows. *Journal of Dairy Science* 96, 3028-3033. https://doi.org/10.3168/jds.2012-5737
41. St-Pierre, N. R., Cobanov, B., Schnitkey, G. (2003): Economic loses from heat stress by US livestock industries. *Journal of Dairy Science* 86, 52-77. https://doi.org/10.3168/jds.S0022-0302(03)74040-5
42. Valtorta, S.E., Leva, P.E., Gallardo, M.R. (1997): Evaluation of different shades to improve dairy cattle well-being in Argentina. *International Journal of Biometeorology* 41, 65-67. https://doi.org/10.1007/s004840050055
43. Vitali, A., Sagnalini, M., Bertocchi, L., Bernabucci, U., Nardone, A., Lacetera, N. (2009): Seasonal pattern of mortality and relationships between mortality and temperature humidity index in dairy cows. *Journal of Dairy Science* 92, 3781-3790. https://doi.org/10.3168/jds.2009-2127
44. West, J.W (2003): Effects of heat-stress on production in dairy cattle. *Journal of Dairy Science* 86, 2131-2144. https://doi.org/10.3168/jds.S0022-0302(03)73803-X
45. West, J.W., Hill, G.M., Fernandez, J.M., Mandebvu, P., Mullinix, B.G. (1999): Effect of dietary fiber on intake, milk yield, and digestion by lactating dairy cows during cool or hot, humid weather. *Journal of Dairy Science* 82, 2455-2465. https://doi.org/10.3168/jds.S0022-0302(99)75497-4