Agronomy Research **19**(1), 210–223, 2021
https://doi.org/10.15159/AR.21.014

Study of influence of heat stress on some physiological and productive traits in Holstein-Friesian dairy cows

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Received: October 6th, 2020; Accepted: February 1st, 2021; Published: March 18st, 2021

Abstract. The aim of the research was to study the effect of heat stress (HS) on some physiological and productive traits in Holstein-Friesian dairy cows. The study included 22 cows on different parities. In the building where the cows were housed, the temperature-humidity index (THI) was reported at 10:00 and 15:00 h, at the same time the rectal temperature (RT) and respiratory rate (RR) were reported for each of the examined cows. The daily rumen activity was taken from the SCR system by Allflex. The average THI values in May were 71, in June - 75, in July - 74, and in August - 77, from which it follows that in the summer months the cows were in conditions of mild to moderate heat stress throughout the day. The average daily milk yield of the cows increased from May to June and reached 41.44 kg day^{-1}, then decreased in July and August to 37.2 and 32.48 kg day^{-1}, respectively. With an increase in the THI values, an increase in the RR and RT was registered, as in THI above 79 the RR was 56.54 per min, and the RT was 39.33 °C. With increasing the THI values, the rumination of the cows decreased from 563 per day at THI < 72 to 542.5 at THI > 79. In cows with high daily milk yield, a higher RT was registered, and in cows with more than 50 kg per day, the RT was 39.09 °C. A more intense rumination was found in cows with higher daily milk yield. In cows with an average daily milk yield of 33.26 kg, an average of 450 ruminations per day were reported, and in those with an average milk yield of up to 42.89 kg - 650 ruminations per day. From the research conducted it was found that the studied physiological traits - rectal temperature, respiration rate and rumination are influenced by HS and the intensity of this effect depend on the daily milk yield of cows and THI levels.

Key words: dairy cows, heat stress, rectal temperature, respiratory rate, temperature-humidity index.

INTRODUCTION

Reports from international and government research centers show alarming trends for systematic global warming (Herbut et al., 2018). Some studies suggest that by 2050 the planet's temperature will rise by 2 °C (Trnka et al., 2011) this warming is expected to have a significant impact on the welfare and productivity of farm animals and in particular dairy cows in many climatic zones around the world (Cook et al., 2005;

De Palo et al., 2006; Herbut et al., 2018). Due to the continuous increase in productivity in dairy cows, there is an increased sensitivity to high ambient temperatures and it is very likely that they will fall into a state of heat stress at lower temperatures (Herbut et al., 2019). Physiological traits such as rectal temperature, skin temperature, vaginal temperature), respiration rate, and pulse rate are widely used as indicators for HS in dairy cattle (e.g. Silanikove, 2000). According to Lee (1965), stress can be caused by all external interventions that affect the body and provoke a series of reactions to maintain its homeostasis. Respiration rate is the first visible response of cattle to heat stress and oscillates with thermal environment (Milan et al., 2016). Brown-Brandl et al. (2005) confirmes that physiological parameters respond earlier to HS than production-related parameters (feed intake and feeding behavior) or behavior changes (shade usage). According to the authors Respiration rate is considered as the most appropriate indicator to monitor HS, i.e. RR is the most valuabe indicator among all physiological, productive, and behavioral indicators. Physiological traits (RT and RR) were also used as predictors of the decline in milk production traits and feed intake during moderate stress in multiparous US Holstein (Spiers et al., 2004). There are many studies in the literature on the effect of HS on dairy cows in subtropical and tropical climates, but according to Roth (2017), heat stress in cows is no longer a characteristic only of the hot regions of the planet. Studies on the negative effects of high temperatures on animals in temperate and Mediterranean regions of Europe are also beginning to appear in the literature (Bernabucci et al., 2014). Some studies by climatologists and meteorologists indicate that global warming poses a threat to the whole of Europe (Peltonen-Sainio et al., 2010).

The aim of the study was to determined the effect of heat stress on some physiological and productive traits in Holstein-Friesian dairy cows under conditions of the temperate continental climate.

MATERIAL AND METHODS

The study was conducted in the period between May and August 2018 on a dairy cattle farm with Holstein-Friesian cows in the region of Karnobat, Southeastern Bulgaria (42°38'46.2"N 26°47'14.0"E). Cows were housed in a semi-open free-stall dairy barn, fed year-round ad libitum with a total mixed ration. On the farm, the cows were cooled by water sprinklers in the holding area of the milking parlor and all a day ventilation in the barn during the warm months of the year. The study included the cows calved between 1st of April and 10^{th} of May 2018, thus excluding the effect of the lactation stage. The included cows were at first (9), second (6), third and more parity (7) in a total of 22 cows. The daily milk yields of the cows included in the studywere taken from their official monthly milk performance records (May and August). To measure the heat stress, a temperature-humidity index was estimated using a 'Kestrel' automatic measuring instrument (https://kestrelmeters.com/products/kestrel-5200-professional-environmental-meter). THI was measured in the cows housing premises twice a day, at 10 am and 3 pm, as at the same time the physiological traits RT and RR per min of each cow were also recorded once at 10 am and once at 3 pm. RT was measured by a digital thermometer in degrees Celsius. RR was reported by visual observation and recording of the movement of the chest for a period of one min according to the method of Zimbelman et al. (2009). The data on the rumen activity, expressed by the number of ruminations for 24 hours, were taken from the farm management software. This activity was reported by belts placed on the neck and fixed to them microphones of the SCR system by Allflex, with which each rumination of the cows was registered. The daily milk yield, as well as the content fat and protein percentage of the cows included in the study, were taken from their official monthly milk performance records (May and August).

For a better approximation, the factors subject to the study were presented in classes as follows:

THI is presented in three classes according to the THI scale proposed by Armstrong (1994), respectively: Class 1 - THI up to 72 (optimal thermal conditions); Class 2 - 72 to 79 (mild heat stress conditions) and Class 3 - THI above 79 (moderate heat stress conditions).

Daily milk yield: Class 1 - up to 30 kg day^{-1}; Class 2 - from 30 to 40 kg day^{-1}; Class 3 - from 40 to 50 kg day^{-1} and Class 4 over 50 kg day^{-1}.

Rectal temperature: Class 1 - up to 38.5 °C; Class 2 - from 38.5 to 39 °C; Class 3 to 39 to 39.5 °C and Class 4 - above 39.5 °C.

Respiratory rate per min: Class 1 - up to 40 per min; Class 2 - 40 to 45 per min; Class 3 - 45 to 55 per min and Class 4 - over 55 movements per min.

The rumination: Class 1 - up to 450; Class 2 - from 450 to 550; Class 3 - from 550 to 650; Class 4 - over 650 ruminations in 24 hours.

For basic statistical processing of the data a package MS Excel was used, and for obtaining the average values, errors, and analysis of variance, the corresponding modules of STATISTICA of StatSoft (Copyright 1990–1995 Microsoft Corp.)

The following model was used to assess the influence of controlled factors on the THI values:

$$Y_{ijkl} = \mu + M_i + H_j + M \cdot H_k + e_{ijkl} \quad (1)$$

where Y_{ijkl} – is the dependent variable (THI values); μ is the mean effect; M_i – is the effect of the month of reporting; H_j is the effect of the hour of reporting; $M \cdot H_k$ is the associated effect of the month and hour of reporting and e_{ijkl} is the random residual effect.

The following model was used to assess the influence of controlled factors on physiological traits:

$$Y_{ijk} = \mu + THI_i + L_j + e_{ijk} \quad (2)$$

Y_{ijk} – is the dependent variable (each of the studied physiological traits); μ is the mean effect; THI_i – is the effect of the *THI* (in classes); L_j– is the effect of the daily milk yield, and $\mathbf{e_{ijk}}$ is the random residual effect.

By analysis of variance for the model were obtained by classes of fixed factors the means of least squares (*LSM*).

RESULTS AND DISCUSSION

Table 1 presents the average values and the variation of THI by months of reporting. Only in May the average THI values were below 72. Tapkı & Şahin (2006) found that in the conditions of the eastern Mediterranean region of Turkey during the months from June to August, dairy cows were also under conditions of heat stress, as we found in temperate continental climate in our study.

Table 2 presents an analysis of variance for the influence of the month and the hour of reporting on the values of THI, the data showed that each of the studied factors, as well as the combination between them, significantly ($P < 0.001$) influenced the THI values. The effects of hour of reporting and month of reporting well represented the thermal conditions in the premises for the animals during the day.

Table 1. Average values and variation of *THI* by months of reporting

Month of reporting	THI x ± SE	min	max
May	71.72 ± 0.30^{a}	69.3	74.2
June	75.06 ± 0.26^{b}	71.8	81.5
July	74.32 ± 0.16^{c}	71.6	77.6
August	77.35 ± 0.33^{d}	74.5	81.5
Average	74.62 ± 0.16	69.3	81.5

a, b, c, d – the differences are significant at $P < 0.05$.

Table 2. Analysis of variance for the influence of the month and hour of reporting on the values of THI

Sources of variation	Degrees of freedom (n–1)	THI MS	F	P
Total for the model	7	148.34	56.45	**
Month of reporting	3	225	85.8	***
Hour of reporting	1	354	134.8	**
Month* Hour of reporting	3	16	6.0	***
Error	242	3		

*** – the differences are significant at $P < 0.001$.

Fig. 1 shows the LS mean values of THI by month and hour of reporting in the period May–August 2018. The study found that only in May, the values of THI, reported at 10:00 am were in the range of temperature comfort, THI < 72. According to Armstrong (1994), at these values of THI cows are in optimal thermal conditions of the environment. In June and July, both morning and afternoon THI values showed that the cows were under conditions of mild HS almost all day. The highest values of THI were reported in August when the morning values were 75.5 and the afternoon 79.2. These values showed that in August the cows on the studied farm were under conditions of moderate to severe heat stress almost all day. Although during the summer fans were operating in the barn, the reported THI values showed that this did not contribute to the betterthermal comfort of the cows. Our results confirm the study of Dimov et al. (2017), who found under the conditions of Southern Bulgaria in buildings for dairy cows of the same type that the values of THI in the summer vary from 74.13 in the building to 76.12 outside it. In their study, the same authors found that the actions taken to cool the cows in the buildings can reduce the values of THI by only up to 2.5 units in the spring and by about 2 units in the summer, which is not enough to achieve conditions of thermal comfort for the animals.

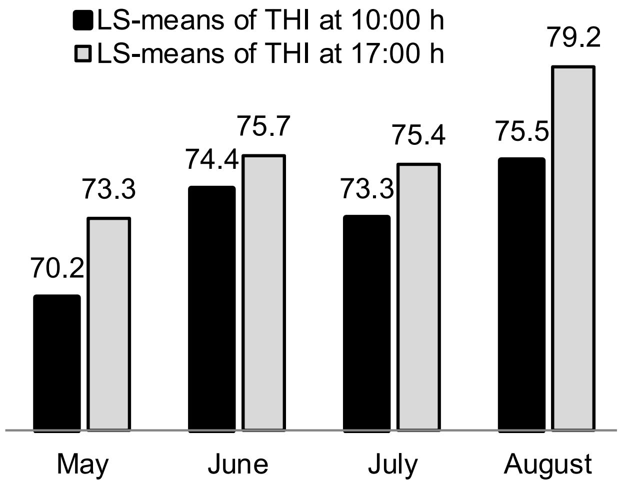

Figure 1. LS-mean values of THI by months and hour of reporting during the period May-August.

Table 3 presents the average values for the productive and physiological traits by months of reporting. The highest daily milk yield in cows included in the study was reported in June - 41.44 kg and the lowest in August 32.48 kg. Regarding the rectal temperature, there was a tendency to increase the average measured rectal temperature from May to August from 38.49 to 38.95 °C. In the RR per min, the lowest values were reported in May - 38.28, and the highest in August - 47.9. In the trait, rumination was found that the highest values were in May - 570.95, and the lowest in June - 521.5 per day, after which their number increased and reached the values for May. This decline in ruminations in June was probably due to the rapid onset of heat stress from May to June, which did not allow cows to adapt to new environmental conditions. According to Bernabucci et al. (1999) at the onset of HS, as an initial reaction a decrease in the movement of the rumen is observed, and in the rumination, respectively. The authors found that with prolonged exposure to HS, the animals acclimatize, whereby the movement of the rumen is restored to the values reported before HS, which was reported as a trend in our data for July and August also.

Table 3. Average values for productive and physiological traits by months of reporting

Month of reporting	No	Daily milk yield, kg	Ruminations number, 24h	No	Rectal temperature, °C	Respiratory rate, min
	n	x ± SE	x ± SE	n	x ± SE	x ± SE
May	21	41.17 ± 2.53	570.95 ± 13.81	42	38.49 ± 0.06^{a}	38.28 ± 1.32^{a}
June	42	41.44 ± 1.72	521.50 ± 11.64	84	38.85 ± 0.05^{b}	45.57 ± 1.09^{bc}
July	42	37.20 ± 1.22	572.90 ± 9.47	84	38.90 ± 0.04^{b}	43.47 ± 1.05^{b}
August	20	32.48 ± 1.59	563.40 ± 11.72	40	38.95 ± 0.07^{b}	47.90 ± 1.64^{bd}
Average	125	38.54 ± 0.90	573.78 ± 6.16	250	38.83 ± 0.03	44.02 ± 0.64

a, b, c, d – the differences between the months are significant at $P < 0.05$.

The data in Table 3 show that the average values of rectal temperature and respiration rate increased from May to August. Body temperature is an important physiological indicator that is indicative of the health of dairy cows (Hicks et al., 2001). A number of studies have shown that high ambient temperatures lead to a significant increase in body temperature and respiration rate in dairy cows (Brown-Brandl et al., 2005; Collier et al., 2006). Table 3 shows that rectal temperature and respiration rate were the physiological traits that increased during the warmest months of the study (June - August). It should be noted that in the respiration rate a certain decrease in July compared to June was observed. This decrease in respiratory rate fully corresponds to the THI data presented in Table 1. In July the average values for THI were 74.32, and in June 75.06. In July, lower morning and afternoon values of THI were reported (Fig. 1). According to Atkins et al. (2018) the intensity of respiration in dairy cows is the most accurate physiological indicator of the effect of HS on them. The results of our study showed that the respiration rate was the physiological trait indicating a direct dependence on environmental conditions - the values of THI. According to Bohmanova et al. (2007) the influence of HS varies depending on the characteristics of the climate, as in a humid climate, such as in our study, the influence of air humidity is stronger than the temperature of the environment. According to Hansen (2007), with increasing daily milk yield, cows produce more metabolic heat, which makes them even more sensitive to HS.

In our study, the daily milk yield of cows was relatively high. In addition, cows were in the first part of lactation, when their productivity is highest, respectively, and their sensitivity to HS.

Table 4 presents an analysis of variance for influence of THI and daily milk yield on the studied physiological traits in dairy cows it was found that THI had effect with high significance ($P < 0.001$) on the values of rectal temperature and respiratory rate, but no significant effect was observed on cow rumination, the level of daily milk yield had a high significant effect on the three studied physiological traits ($P < 0.001$). Studies by other authors West et al. (2003); Gaworski & Rocha, (2016); Pilatti et al. (2018) found that HS leads to a number of physiological and behavioral disorders.

Table 4. Analysis of variance for influence of THI and daily milk yield on the studied physiological traits

Sources of variation	Degrees of freedom (n–1)	Respiratory rate F P	Rectal temperature F P	Ruminations F P
Total for the model	5	9.85***	14.48***	13.92***
THI	2	21.17***	26.1***	0.15 n.s
Milk yield	3	5.61***	12.7***	13.58***
Error	244			

* – significant at $P < 0.05$; ** – significant at $P < 0.01$; *** – significant at $P < 0.001$; *n.s.* – no significant effect.

Fig. 2 shows the LS-mean values for respiratory rate depending on THI. The data showed that with increasing THI the respiratory rate increased, the differences between conditions out of HS (THI < 72) and in mild HS (THI 72-79) were less than 4 breaths per min. With the onset of moderate HS at THI > 79, the LS-mean values for respiratory rate reached 56.54 breaths per min or 13 breaths min^{-1} more compared to mild HS (THI 72–79) and 17 compared to temperature comfort conditions (THI < 72). Lemerle & Goddard (1986) found that respiratory rate began to increase before THI values reached 73, with a sharp increase observed at THI > 80. Our results completely confirm these studies. In the acute phase of HS, the respiratory rate can reach 60–70 breaths min^{-1} (Collier et al., 2012). According to Dalcin et al. (2016) the number of respiratory movements per min is the best physiological indicator that reflects the effect of HS on dairy cows.

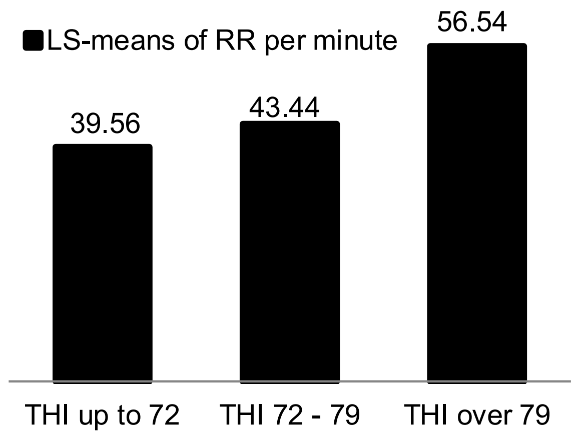

Figure 2. LS-mean values for respiratory rate depending on the values of THI.

Fig. 3 shows the respiratory rate depending on the daily milk yield of the cows. A slight increase in respiration rate in cows with higher daily milk yield was observed, this increase in RR was not so linear in accordance to the level of daily milk yield, as observed in relation with the THI level, it can be said that the intensity of RR increased in cows with daily milk yield over 40 kg compared to those with lower daily milk yield, all this showed that the respiratory rate in cows was more strongly influenced by the level of HS than by milk yield level. According to Pinto et al. (2019) for each kilogram of milk production an increase of RR with 0.23 breaths per min was reported. Our results showed an increase in respiratory rate of 6.7 breaths per min in cows with daily milk yields over 40 kg compared to those with daily milk yields up to 30 kg. This effect of milk performance level on the respiration rate in dairy cows was a consequence of the increased metabolism in the body of high producing animals.

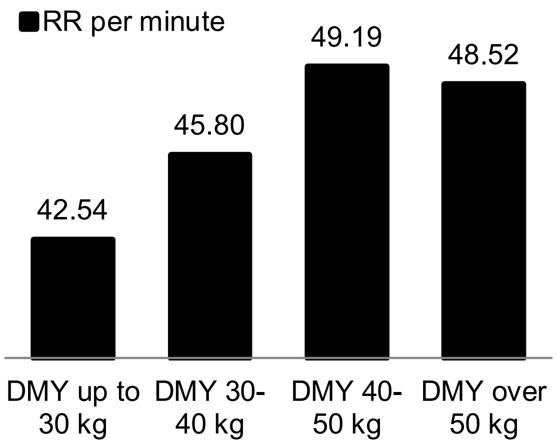

Figure 3. Respiratory rate depending on daily milk yield.

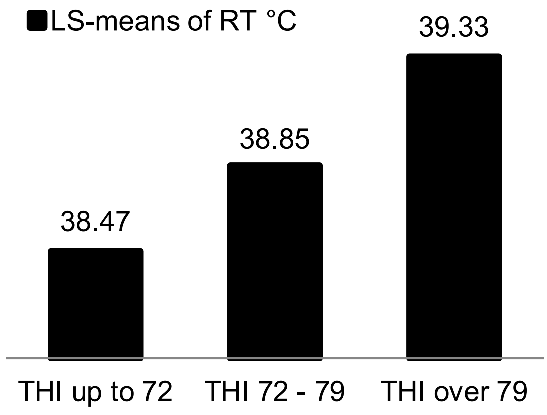

Figure 4. LS-mean values of rectal temperature depending on THI.

Fig. 4 shows the LS-mean values for rectal temperature depending on THI, it was found that with the increase of the values of THI the values of the rectal temperature also increase. The difference in the reported rectal temperature under optimal thermal conditions (THI < 72) and mild HS conditions (THI from 72 to 79) was minimal - less than 0.5 °C. With the onset of moderate HS conditions (THI > 79), the rectal temperature reached 39.33 °C. Although the differences in rectal temperature values between the different classes of THI were not as large as those observed in the respiratory rate, the reported increase in the values was significant from a physiological point of view. According to Ammer et al. (2016) the normal range of rectal temperature in dairy cows ranged from 38 to 39.2 °C. Our results showed that under conditions of moderate heat stress (THI > 79) the values of the rectal temperature in dairy cows exceeded the physiological range. The study of Zimbelman et al. (2009) is consistent with our results. According to the authors, the effect of THI on dairy cows also depends on their daily milk yield. Zimbelmann et al. (2009) found that in cows with a daily milk yield of 35 kg day^{-1}, the values of THI, which have a negative impact on their body, are lower - THI 68, compared to the lower producing ones.

Fig. 5 presents the LS-mean values of rectal temperature depending on daily milk yield. The mean values of the rectal temperature increased in cows with higher daily milk yield, as in cows with daily milk yield up to 30 kg day^{-1} it was 38.61 °C, and in those with more than 50 kg day^{-1} - 39.09 °C. The higher rectal temperature of cows with higher daily milk yield was due to the fact that they digested more feed, produced more metabolic heat, which in turn makes them more sensitive to HS (Kadzere et al., 2002). For this reason, the regulation of body temperature in highly producing dairy cows under HS conditions is more difficult (Berman et al., 1985; Umphrey et al., 2001; Berman, 2005).

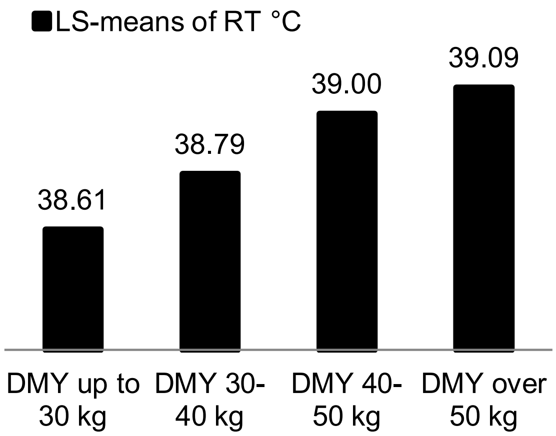

Figure 5. LS-mean values of rectal temperature depending on daily milk yield.

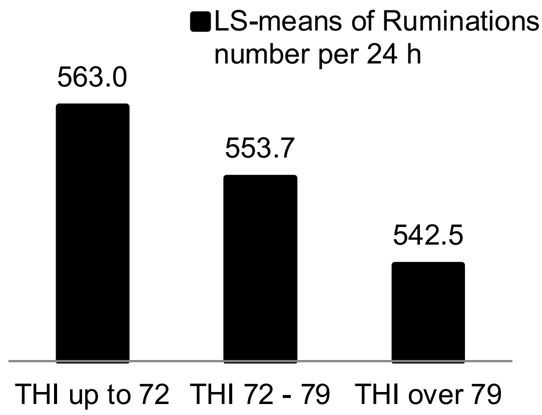

Figure 6. LS-mean values of ruminations depending on THI.

Fig. 6 shows the LS mean rumination values depending on the THI values, with the highest LS mean values of ruminations were cows under thermal comfort conditions (THI up to 72), and the lowest in cows under conditions of moderate HS (THI over 79), 563 and 542.5 ruminations in 24 hours, respectively. Our results, confirmed the studies of Tapkı & Şahin (2006), which also found a decrease in cow rumination with increasing ambient temperature, this decrease may be due to a reduction in roughage intake at the expense of concentrated feed under HS (Coppock & West, 1986), this behavior is considered to be the adaptation of cows to reduce the heat generated during fermentation in the rumen (Beede & Shearer, 1991). On the other hand, under HS, ruminants drink more water (Roger & Davis 1982; Muna & Abdelatif, 1992), which makes the contents of the rumen more fluid and thus reduces the number of ruminations and belching, respectively. Another probable reason for the decrease in the number of ruminations in dairy cows is that under HS the thermoregulatory center in the hypothalamus is activated, which, through the vagus nerve, reduces the motor activity of the stomach compartments (Varlyakov et al., 2012), as a result of the reduced motor activity of the rumen, the speed of the feed passing through the stomach compartments is slowed down (Bernabucci et al., 1999).

Bernabucci et al. (1999) found that with short-term exposure to HS, the rate of nutrient degradation in forestomachs of ruminants decreased, but with long-term exposure, it remained close to those reported under temperature comfort conditions. According to the authors, this was an adaptation of the animals to the conditions of HS. The speed, at which feed passes through the stomach compartments, as well as the degree of nutrient degradation, is of great importance for the productivity of cows. From the data presented in Fig. 7 it can

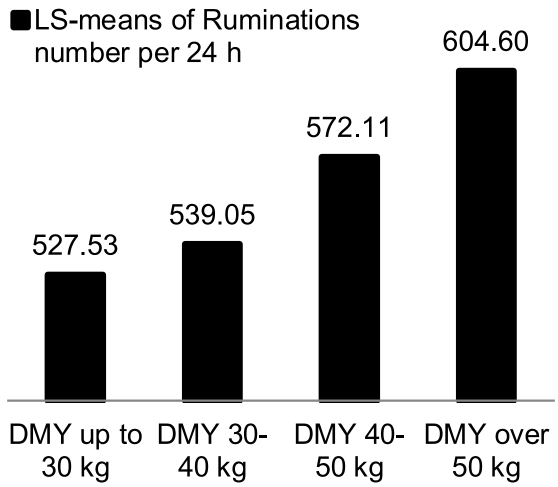

Figure 7. LS-mean values of ruminations depending on daily milk yield.

be seen that with the increase of the daily milk yield the number of ruminations for 24hours also increased, in a study by Tapkı & Şahin (2006), higher-yielding cows in the morning at lower ambient temperatures spent more time ruminating than lower-yielding cows.

The relationship between thermal conditions, physiological indicators and productivity in dairy cows is not unidirectional, on the one hand, high temperatures negatively affect a number of physiological indicators and productive traits in dairy cows, and on the other hand the level of milk productivity of animals is a prerequisite for higher values of a number of physiological indicators and higher sensitivity to HS. Table 5 presents an analysis of the variance for the effect of THI, respiration rate, rectal temperature and ruminations number on the daily milk yield of the cows included in the study, the presented data show that all controlled factors had an impact on the daily milk yield of cows. The effect of the individual factors on milk yield is presented in more detail in graphical form in Figs 8–11, respectively.

Table 5. Analysis of variance for the influence of THI, respiratory rate, rectal temperature and ruminations on Test day milk yield

Sources of variation	Degrees of freedom (n–1)	Test day milk yield, kg MS	F P
Total for the model	11	768.01	10.92 ***
THI	2	1,440.28	20.47 ***
Respiratory rate	3	478.93	6.81 ***
Rectal temperature	3	599.90	8.53 ***
Ruminations	3	414.41	5.89 ***
Error	238	70.36	

*** – significant at $P < 0.001$.

Fig. 8 shows the LS means for daily milk yield depending on THI values. The highest daily milk yield of cows was reported under optimal thermal conditions (THI < 72), 45.62 kg day^{-1}, respectively. With increasing values of THI, the daily milk yield of cows decreased, as under conditions of mild HS (THI from 72 to 79) the average milk yield was 38.90 kg day^{-1}, and under conditions of moderate HS (THI over 79) it was 28.95 kg day^{-1}. However, the data in Table 3 show that the highest average daily milk yield was reached in June, when high values of THI were registered during the morning and afternoon measurements (Fig. 1) - 74.4 and 75.7, respectively, and at the same time, the ruminations number of the cows was the lowest (Table 3). All this confirms the significant influence of THI on the daily milk yield of cows. The decrease in productivity under HS may be due to a decrease in the amount of dry matter intake. Baumgard et al. (2011) believe that reduced dry matter intake can explain only 35–50% of reduced milk yield. According to Slimen et al. (2016) HS causes a reorganization in the use of body resources such as fat, protein and energy, which is the other reason leading to reduced productivity.

Fig. 9 shows the LS means of daily milk yield depending on the respiratory rate. A linear nature of the dependence of respiratory rate on milk productivity of cows was not reported. The highest respiratory rate (over 55) had cows with 38.35 kg day^{-1}, while those with the highest milk yield - 40.97 kg day^{-1} had a respiratory rate of 40–45. The influence of HS on cows depends on many factors, such as breed, age, productivity, stage of lactation, as well as on earlier influence of HS (Zimbelman et al., 2009). According to the authors, more productive cows are more sensitive to HS, but physiological responses such as respiratory rate do not correspond directly to the heat load of the animals. It was found that there is some delay in the physiological response of animals to HS. Gaughan et al. (2000) found a 2-hour delay in increasing respiratory rate after an increase in THI values. According to Atkins et al. (2018) the presence of cooling systems, as there were in the farm we studied, can also affect the respiratory rate of cows. All this is probably the reason for the observed variations in the presented figure.

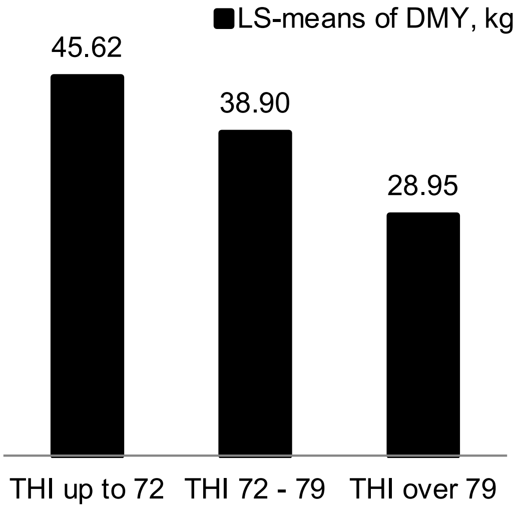

Figure 8. LS-mean values of daily milk yield depending on THI.

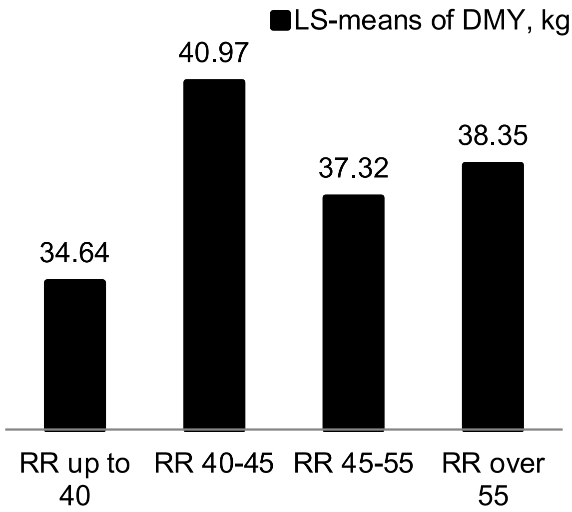

Figure 9. LS-mean values of daily milk yield depending on the respiratory rate.

Fig. 10 shows the LS means for daily milk yield depending on rectal temperature. The cows with a rectal temperature of up to 38.5 °C had the lowest daily milk yield of 32.45 kg day^{-1}, and the cows with a rectal temperature of 39 to 39.5 °C had the highest daily milk yield of 41.01 kg per day. In cows with a rectal temperature above 39.5 °C, the daily milk yield was just over 40 kg day^{-1}. There was a tendency to increase the rectal temperature in cows with high milk yield. According to Dikmen & Hansen (2009), the regulation of body temperature in cows in conditions of hyperthermia can be expected to be ineffective with an increase in daily milk yield due to the metabolic release of more heat. However, in their study, the authors did not find such a relationship. Berman et al. (1985) found a higher rectal temperature in cows with higher milk yields. According to Dikmen & Hansen (2009), the lack of relationship between rectal temperature and milk yield of cows may be due to the fact that daily milk yield of cows was not recorded on the same day as rectal temperature was measured.

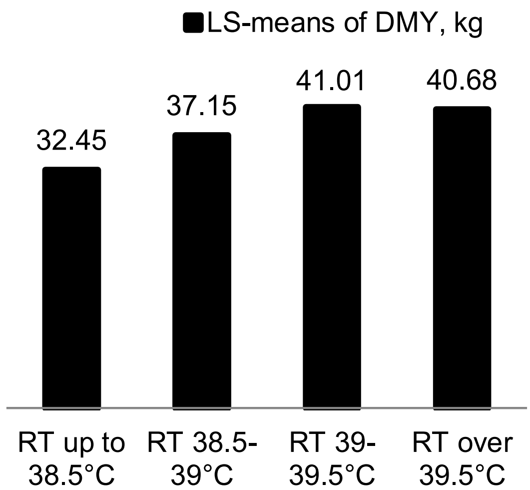

Figure 10. LS-mean values of daily milk yield depending on rectal temperature.

Fig. 11 shows the LS means of daily milk yield depending on ruminations. With the lowest milk yield - 33.26 kg per day were the cows with the lowest number of ruminations - up to 450 per day. In cows with high milk yield an increase in rumination was reported, and in cows with 42.89 kg day^{-1} the ruminations number reached over 650 per day. All this shows that the daily milk yield of dairy cows on the studied farm depended on the activity of the forestomachs, respectively on the number of ruminations and belchings of the cows. Our results were also confirmed by the studies of Antanaitis et al. (2018), who found a higher number of ruminations in cows with higher daily milk yield. The data presented in Table 3 show that with the onset of HS in June, rumination in cows decreased, but in July and August it returned to levels measured in May, when the cows were under conditions of temperature comfort. According to Bernabucci et al. (1999) digestive tract of ruminants can adapt when the exposure to HS is in a long-term.

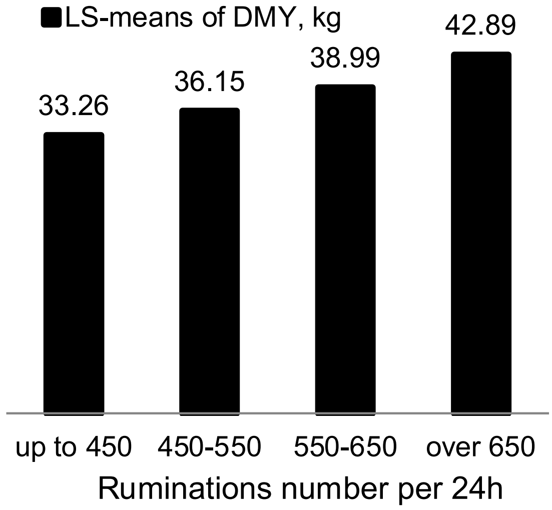

Figure 11. LS- mean values of daily milk yield depending on ruminations.

CONCLUSION

Based on the study, it was found that under conditions of mild to moderate heat stress, rectal temperature and respiratory rate increased. With the onset of HS, the rumen activity decreased, and subsequently, when the cows adapted, the activity of the rumen was returned to the values registered in the thermo neutral months. Changes under the influence of HS in the studied physiological traits - rectal temperature, respiratory rate and rumination number depend also on the milk performance of cows. In cows with higher daily milk yield under HS conditions, a more pronounced increase in rectal temperature and respiratory rate was observed. With an increase in HS expressed by the values of THI, a decrease in the rumen activity was reported, as well as a decrease in the daily milk yield of cows. The study proved that in cows with higher daily milk yield changes in physiological parameters - rectal temperature, respiratory rate and rumination number are more strongly expressed under the influence of HS.

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