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The Effect of Heat Stress on Milk Yield, Milk Fat Rate and Rectal Temperature in Holstein-Friesian Dairy Cattle

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ABSTRACT

Heat stress is an environmental factor that negatively affects the morphological and physiological properties of dairy cattle. The aim of this study is to investigate the relationship between heat stress and milk yield, milk fat ratio and body temperature in Holstein-Friesian dairy cattle. The data of the study was obtained from a private Kurtalan Farm of Siirt province, the Southeastern Anatolia Region of Turkey. Milk yield and other traits of 13 head Holstein-Friesian dairy cattle were recorded in March, April, May, June, July, August and September. In addition, temperature and humidity records were recorded in the farm and in the parlor to be used for calculating the temperature humidity index value. In the analysis of data, correlation and regression methods were used. As a result of the study, the negative correlation (P<0.01) was found between milk yield and milk fat ratio and the positive correlation (P<0.001) were detected between heat stress and body temperature. In addition, a significant negative relationship was observed between rectal temperature and milk yield (P<0.01).

1. Introduction

Animal husbandry is important in terms of adequate and balanced nutrition of people and consumption of animal-derived proteins such as meat, milk and eggs that determine the level of development of countries (Hekimoğlu and Altındeğer, 2008). In order to meet the needs of the increasing world population such as meat and milk, the productivity per animal needs to be increased. Factors affecting the productivity of animals are examined under two main headings as genetics and environmental factors (Tuncel, 1994). Among environmental factors, care, feeding and climate factors come to the fore. Although temperature, humidity and wind come to the fore among the climate factors, it is seen as the most important factor since the temperature factor affects the productivity of the animals negatively (Mutaf and Sönmez, 1994; Öten et al., 2010). When the temperature occurred by the ambient temperature and humidity values (Thom, 1959) exceeds the humidity index threshold values, the animals are exposed to heat stress. Studies have reported that heat stress begins when the temperature humidity index value exceeds 65 and mortality rates increase when it exceeds 80 (Vitali et al., 2009; Collier et al., 2011). Many studies have been conducted to show that the heat stress negatively affects milk yield (West, 1999; West et al., 2003; Brouček et al., 2009; Baumgard et al., 2012; Brown et al., 2015; Al Reyad et al., 2016; Trajchev et al., 2016; Zhu et al., 2016) and milk fat rate (Arieli et al., 2004; Rejeb et al., 2012; Brouček et al., 2009; Ghavi Hossein-Zadeh, 2013). However, studies reporting that heat stress negatively affects the reproductive characteristics of animals have also been conducted (Evans et al., 2010;Khodaei-Motlagh et al., 2011; El-Wishy, 2013).This study aimed to investigate the effect of heat stress on milk yield, milk fat ratio and body temperature in Holstein-Friesian dairy cattle.

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2. Materials and Methods

This study was carried out in a private Agricultural Enterprise located in Gökdoğan village of Kurtalan district of Siirt province. The enterprise is located in the Southeastern Anatolia Region, where the continental climate prevails and the temperatures can rise 42 °C in August (Figure 1). The animals are housed in semi-open shelters (Figure 2).

Figure 1
Geographical location of Siirt province

Figure 2
Business where the study is carried out

Feeding is done two times a day after morning and evening milking. Milking is done automatically between 05:00-07:00 in the morning and 17:00-19:00 in the evening. 21 kg corn silage, 10 kg concentrate and 3 kg wheat straw are given per animal. In addition, when corn harvest is made, wheat straw is halved and 1.5 kg corn straw is used instead. The feedstuffs used were analyzed for dry matter (DM), crude protein (CP), crude fat (CF), crude ash (CA), acid detergent cellulose (ADC) and neutral detergent cellulose (NDC) (Table:1)

Table 1
Nutrient content of feeds used for farm

Nutrient contents, %	DM	CP	CF	CA	ADC	NDC
Corn straw	91.18	3.05	1.29	6.57	54.14	75.05
Wheat straw	92.61	2.84	1.40	6.32	57.39	74.23
Corn silage	95.05	4.90	1.61	7.92	34.93	61.21
Concentrated feed	88.61	18.01	4.26	7.94	9.17	27.48

In determining the cattle, the calving date and milk yields of the cows were taken into account. Because there are no farms in Siirt province that uses herd management program or support academic studies, 13 animals were used in the current study. Accordingly, study started with 9 animals giving birth in March and 4 animals giving birth in April. Three of these animals were first, five of these animals were second twoof these animals were third, one of these animals was forth and two ot these animals were seventh lactation. The selected animals were kept with other animals and no different treatment was made. Samples collecting were started in a week after birth in order to lose the effect of colostrum milk and continued from March to September. Milking was performed with an individual milking machine, milk samples were taken and milk yield was recorded. After milking, the rectal temperatures of the animals were measured with a thermometer. During milking, environmental temperature and humidity values were recorded with a temperature and humidity recorder. The milk samples were analyzed immediately on the milk analyzer.The temperature and humidity recorder placed in an area where the animals spend the most time in the shelter and where the sun does not directly contact, the environmental temperature and humidity values were recorded every two hours. In calculating the temperature and humidity index (THI) in the shelter and in the parlorthe Formula (1)

THI = (0.8 * Tdb) + ((RH / 100) * (Tdb-14.4)) + 46.4 (1) was used (Mader et al 2006).

For statistical analysis, milk yield and milk fat ratio were selected as dependent variable, months, lactation number, rectal temperature and temperature humidity index values were evaluated as independent variables. Also rectal temperature was evaluated as dependent variable. Since the measurements are in a longitudinal (repetitive) structure obtained at 7 different time points for each animal, analyzes have been carried out in a linear fixed-effect mixed model structure that takes into account repeated measurements.

2.1. Model

$$Y_{ijkl} = \mu + a_i + b_j + b_1 (x_{ijkl} - \bar{x}) + b_2 (x_{ijkl} - \bar{x}) + e_{ijkl}$$

Y_{ijkl} = Daily milk yield, milk fat ratio and rectal temperature, μ = average of the population,

a_i = The effect of i. month

b_j = The effect of j. lactation period,

b_1 = regression coefficient of milk yield and milk fat ratio according to temperature humidity index values during milking,

b_2 = regression coefficient of milk yield and milk fat ratio according to rectal temperature,

x_{ijkl} = temperature humidity index value and rectal temperature,

$\bar{x}$ = average temperature humidity index value and rectal temperature,

e_{ijklm} = error.

When the rectal temperature is dependent variable, rectal temperature has not evaluated as a independent varible. The most likelihood method was used to obtain model estimates. However, the mean of the least squares for the temperature humidity index at milking point was obtained for each dependent variable. Pearson's correlation coefficients were used in order to determine the relationships between the variables in the continuous structure used in the study and regression models were created between the features whose relationship was significant. In addition, the mean, standard deviation, minimum and maximum values and 95% confidence limits for the mean variables are given as descriptive statistics. SAS 9.4 software was used for the statistical evaluation of the data. Proc Means, Proc Corr and Proc Mixed commands were used to perform analysis. Also, some regression models were constituted between the milk yield, rectal temperature, temperature humidity index and milk fat ratio.

3. Results and Discussion

Temperature, humidity and temperature humidity index values obtained during milking and in the shelter are given in Table 2. The highest temperature (41 ^oC) was observed in the shelter in August and September, while the lowest temperature (6.7 ^oC) was detected in April. The highest humidity was experienced in May (90.1%) and the lowest humidity (6.30%) in September. The highest and lowest temperature humidity index values were observed in August (83.36) and April (46.07), respectively. The lowest (11.5 ^oC) and the highest (30 ^oC) temperatures during milking were observed in March and August, respectively. The lowest (46%) and highest (75%) humidity rates were observed in July and May, respectively. However, the lowest (53.54) and highest (77.97) temperature humidity index values were found to occur in March and August, respectively.

Temperature humidity index values obtained from the shelter were found to be higher than the threshold values reported in some previous studies (Vitali et al 2009; Collier et al 2011; Bouraoui et al 2002; Bernabucci et al 2010; De Rensis et al 2015). Although the temperature humidity index values during milking were found several units higher than inside the shelter, it was observed that the temperature humidity index values reached 83.56, 82.96 etc. in some days in the shelter. It has been determined that dairy cattle are exposed to heat stress from the middle of May to the end of September in the current farm. In other words, the farm experiences about 5.5 months of heat stress within a year. This shows that the region has a warm climate. The use of fan and wetting methods, semi-open shelters and canopies in the farms ensures that the temperature and humidity index values decrease. It is estimated that cattle are exposed to heat stress for a long time and their productivity decreases in the Southeastern Anatolia Region where these methods are used almost negligibly.

In the current study, the rectal temperatures of cattle ranged from 35.6 ^oC (May) to the highest between 39.65 ^oC (August) between March and September. According to the monthly average values, the rectal temperatures of the cattle were determined the lowest in May (36.89 ^oC) and the highest in August (38.48 ^oC) (Table 3). A positive correlation was found between temperature humidity index and rectal temperatures of cattle ($P < 0.0001$). Rectal temperatures of cattle reached their highest values in August, when temperatures increased. In the current study, a negative relationship was determined between rectal temperature and milk yield ($P<0.01$). Heat stress causes the rectal temperatures in cattle to increase and thus to decrease milk yield. The negative relationship between rectal temperature and milk yield determined in this study is in agreement with (Nardone et al 2006)

Table 2
Temperature, humidity and temperature-humidity index values in the farm and during milking

Months	Values	MAT	MAH	MATHI	MPT	MPH	MPTHI
March	Mean	13.95±1.91	61.45±6.41	57.27±2.71	11.50	71.00	53.54
	Sample number	6	6	6			
	Minimum	11.80	52.80	54.08			
	Maximum	16.10	67.90	60.39			
April	Mean	14.95±3.90	69.17±13.65	58.64±5.69	21.00	68.00	67.69
	Sample number	360	360	360			
	Minimum	6.70	31.60	46.07			
	Maximum	26.40	89.60	73.89			

Table 2
Temperature, humidity and temperature-humidity index values in the farm and during milking

May	Mean	19.83±4.61	63.33±16.47	65.11±5.78	19.00	75.00	65.05
	Sample number	373	373	373			
	Minimum	9.20	20.80	49.70			
	Maximum	30.60	90.10	76.97			
June	Mean	24.11±6.17	47.63±19.04	69.19±6.21	25.50	47.50	72.07
	Sample number	336	336	336			
	Minimum	11.50	13.80	53.18			
	Maximum	36.60	87.90	79.09			
July	Mean	29.78±6.33	31.56±13.25	74.29±5.34	30.00	46.00	77.58
	Sample number	385	385	385			
	Minimum	17.10	8.70	61.78			
	Maximum	40.30	67.60	82.96			
August	Mean	30.42±6.57	29.20±13.06	74.61±5.37	30.00	48.50	77.97
	Sample number	228	228	228			
	Minimum	18.60	7.40	63.17			
	Maximum	41.00	56.50	83.36			
September	Mean	28.11±6.61	30.03±11.99	72.33±5.96	26.00	52.00	73.23
	Sample number	504	504	504			
	Minimum	14.30	6.30	57.80			
	Maximum	41.00	56.80	82.30			
Total	Mean	24.42±8.00	45.09±21.86	68.91±8.02	23.28±6.65	58.29±12.50	69.59±8.52
	Sample number	2192	2192	2192	7	7	7
	Minimum	6.70	6.30	46.07	11.50	46.00	53.54
	Maximum	41.00	90.10	83.36	30.00	75.00	77.97

MAT: Monthly average temperature, MAH: Monthly average humidity, MATHI: Monthly average temperature-humidity index, MPT: Milking parlor temperature, MPH: Milking parlor humidity, MPTHI: Milking parlor temperature-humidity index

During the study, the highest (41.7 kg) and the lowest (8.4 kg) daily milk yield was obtained in April, while the average milk yield was determined as 24.39 kg. It was determined that milk yield decreased in the summer months from May to September (Table 3). A significant negative correlation was found between milk yield and temperature humidity index ($P < 0.05$) and rectal temperature ($P < 0.01$). In accordance with this study, it has been reported that heat stress reduces milk yield in different studies (Brouček et al 2009; Brown et al 2015; Al Reyad et al 2016; Gaafar et al 2011; Nardone et al 2006).

The lowest (2.40%) and highest (7.35%) milk fat ratio was obtained in September and April, respectively. A significant negative correlation was found between temperature, humidity index value and milk fat ratio ($P < 0.01$). In different studies, it was determined that heat stress caused a decrease in milk fat ratio (Bouraoui et al 2002; Joksimović-Todorovićet al 2011; Gorniak et al, 2014; Tuyttens et al 2015) and it was found similar to this study.

Regression models between temperature humidity index and rectal temperature, milk yield and milk fat ratio and between milk yield and rectal temperature are as follows;

1. RT (Rectal temperature) = 33.480 + (0.063 x THI)
2. MY1 (Milk yield-1) = 43.104 + (-0.263 x THI)
3. MFR (Milk fat ratio) = 7.001 + (-0.044 x THI)
4. MY2 (Milk yield-2) = 132.843 + (-2.855 x RT)

As the temperature humidity index increases, the rectal temperature of the cattle increases, the milk yield and the milk fat ratio decrease. According to the regression models, for example, while milking temperature humidity index values are 65, 69, 73 and 80, the rectal temperatures of the cattle are 37.58 ^oC, 37.83 ^oC, 38.08 ^oC and 38.52 ^oC, milk yields 26.01 kg, 24.96 kg, 23.91 kg and 22.06 kg and milk fat rates were found as 4.14%, 3.97%, 3.79% and 3.48%.However, according to the regression model between rectal temperature and milk yield, the rectal temperature was 37.58 ^oC, 37.83 ^oC, 38.08 ^oC and 38.52 ^oC, while milk yield was 25.57 kg, 24.85 kg, 24.13 kg and 22.87 kg. In other words, when the temperature humidity index value is less than 71, milk yield is more affected by the increased rectal temperature, and when it is more than 71, it is observed that there is more decrease in milk yield due to the increasing temperature humidity index value. As it continues to rise, it can be interpreted that it is more effective in the beginning when the body temperatures rise faster.

Table 3
Monthly average rectal temperature, milk yield and milk fat ratio values

Months		Rectal temperature (^oC)	Milk yield (kg)	Milk fat (%)
March	Mean	37.25±0.71	26.88±8.80	5.09±0.32
	Animal number	5	4	4
	Minimum	36.40	14.70	4.75
	Maximum	37.95	35.40	5.45

Table 3
Monthly average rectal temperature, milk yield and milk fat ratio values

April	Mean	38.35±0.45	24.72±11.21	4.63±1.35
	Animal number	13	13	12
	Minimum	37.15	8.40	2.75
	Maximum	38.80	41.70	7.35
May	Mean	36.89±0.68	28.06±7.47	3.44±0.56
	Animal number	13	13	13
	Minimum	35.60	11.40	2.55
	Maximum	37.90	40.55	4.25
June	Mean	37.90±0.44	26.38±5.56	3.69±0.64
	Animal number	13	13	13
	Minimum	36.85	18.58	2.45
	Maximum	38.55	34.30	4.60
July	Mean	38.35±0.46	24.63±5.30	3.42±0.57
	Animal number	12	12	12
	Minimum	37.65	15.43	2.45
	Maximum	39.20	31.30	4.25
August	Mean	38.48±0.44	21.54±3.49	3.68±0.57
	Animal number	13	12	13
	Minimum	37.80	15.74	2.85
	Maximum	39.65	27.90	4.60
September	Mean	38.23±0.35	20.07±4.22	4.01±0.78
	Animal number	13	13	13
	Minimum	37.75	12.40	2.40
	Maximum	38.80	26.20	5.60
Total	Mean	37.98±0.74	24.39±7.14	3.87±0.89
	Animal number	82	80	80
	Minimum	35.60	8.40	2.40
	Maximum	39.65	41.70	7.35
	R^2	-	0.354	0.182

4. Conclusion

As a result, it was determined that the rectal temperature increases with the heat stress and milk yield decreases and cooling systems should be used to eliminate these negativities. It has been determined that cattle are exposed to heat stress from mid-May to mid-September, although the current farm is half open and the farm uses 2 fans to cool during milking. It is understood that the cooling system used here is insufficient. Considering this dairy cattle farm, it is considered that more effective fans and wetting methods should be used for cooling the animals in the dairy cattle farms in Siirt province and Southeast Anatolia region where the temperatures are high. In addition, it is expected that artificial shades and afforestation in pastures will be beneficial in reducing heat stress.

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