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Original Article

Effect of the temperature-humidity index and lactation stage on milk production traits and somatic cell score of dairy cows in Iran

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Abstract

The aim of this study was to investigate the effect of the temperature-humidity index (THI) and days in milk (DIM) on milk production traits and somatic cell score (SCS) of dairy cows raised in north area of Iran. To calculate THI, ambient temperature and relative humidity were obtained from the nearest stands. Milk production data included 67,774 test-day records for milk, fat, and protein yield, fat, and protein percentage and SCS. These traits were associated with the average THI of the 3-d preceding the respective measurement, which was divided into five classes, 40-50, 50-60, 60-70, 70-80, and ≥80). Greatest milk yields were recorded in THI≤60 (P<0.05). The highest decrease in milk yield in connection with THI values were recorded in the early lactation (0 to 100 DIM). SCS was positively associated with the THI and increased more in early period of lactation.

Keywords: temperature-humidity index, Lactation stage, milk, somatic cell score

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1. Introduction

Livestock performance is influenced by different elements due to complex interactions between the individual animal and the environment with its different factors (Lambertz *et al.*, 2013).Climatic states may influence the welfare and production of livestock species. In dairy cows, elevated environmental temperature encountered throughout the hot season has an impact on metabolism, physiology, production and reproduction of the animal (Bernabucci *et al.*, 2010; Bertocchi *et al.*, 2014).Some researchers have investigated the seasonal variations in milk yield and composition. Bouraoui *et al.* (2002) reported a significant decline in milk, protein and fat yield and a significant increase in the somatic cell count of Holstein cows during the summer (THI) = 78) compared with spring (THI = 68). Also, Renna *et al.* (2010) observed decline in milk, fat and protein yields during the summer months of the hottest year, 2003. Bertocchi *et al.* (2014) reported a positive correlation between THI and SCC and TBC (total bacterial count), and showed a significant change at 57.3 and 72.8, respectively. Those authors reported a negative correlation between THI and fat and protein percentage and their model reported breakpoints in the pattern at 50.2 and 65.2 maximum THI, respectively. Ravagnolo *et al.* (2000) have observed a decline of 0.009 kg and 0.012 kg in protein and fat yield, respectively, for each unit of THI above the threshold of 72. Milk yield and composition is also influenced by the stage of lactation. For example, Johnson and Young (2003) demonstrated that concentrations of milk urea nitrogen (MUN) was lower for the first 30 DIM compared with all other DIM categories for Holstein and Jersey cows. Because livestock production and welfare is influenced by interactions between the individual animal and the environment, the objective of this study was to investigate the

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effects of heat stress and lactation stage on milk production and composition in Holstein dairy cattle.

2. Material and Methods

2.1 Animals

The study was conducted on two dairy farms located in two parts of Mazandaran province, north of Iran, Sari with hot-summer Mediterranean climate and Babolsar with humid subtropical climate.

2.2 Milk production traits and environmental data

A total of 67,774 test-day records for milk yield, fat and protein yields, fat and protein percentage, and SCC collected from 2005 to 2013 were included in the study. SCS was calculated by taking the logarithm of somatic cell count (SCC): SCS=log2 (SCC/100000) +3. Ambient temperature and relative humidity were collected from the nearest stands. The THI was calculated according to the following formula: $THI = (1.8\times T+32) - (0.55-0.0055\times RH)\times(1.8\times T-26)$, where T is the air temperature in degrees Celsius and RH is the relative humidity in percent (NRC, 1971). The average and maximum THI of the 3 d preceding the milk sampling were used for statistical analysis (Bohmanova *et al.*, 2008; Bruge mann *et al.*, 2011). The 3-d average THI was divided into five classes: 40-50, 50-60, 60-70, 70-80, and ≥80.

2.3 Statistical models

A linear mixed model including random and fixed effects was used to investigate the effect of heat stress on test-day records. Parameters of the test-day records were analyzed using PROC MIXED of SAS 9.2 with the following model: Yijknmo = μ+SLi+PAj+SCk+THIn+F_m(cow) + eijknmo, where Yijkmno = observations for milk yield, fat, and protein yield, fat and protein percentage and SCS; μ = mean effect; SLi= fixed effect of the stage of lactation, i = early (0 to 100 days in milk), mid (101 to 200 days in milk), or late (201 to 305 days in milk); PAj = fixed effect of the parity (5 classes); SCk = fixed effect of calving season (4 classes); THIn = fixed effect of the THI classes (5 classes); F_m (cow) = repeated effect of the cow and eijklmno = random error. The significance of the fixed effects was analyzed by using the Tukey test with a significance level of P<0.05.

3. Results and Discussion

3.1 Temperature-humidity index

In Table 1, the different parameters of the test-day records classified by the THI and DIM are presented. THI had significant effect (P <0.0001) on all studied traits. As given, the greatest milk yields were recorded inTHI≤60. Milk yield decreased significantly as THI increased to ≥60 in a way that milk yield was reduced by 6 % as the THI values moved from 50≤THI≤60 to ≥60.Our result of the unfavorable effect of THI>60 on milk yields is in agreement with the estimates of Brugemann *et al.* (2012) who reported a substantial decline in daily milk yield for THI>60. Our results, however, differed from those of Bohmanova *et al.* (2007) who reported that heat stress in dairy cows mostly occurs in THI≥70.Bouraoui *et al.* (2002) reported that milk yield declined by 21% when the THI increased from 68 to 78. For THI values above 69, the milk yield declined by 0.41 kg/d per cow and THI unit increase. Bernabucci *et al.* (2010) reported a decrease of 0.27 kg milk per day for each THI unit increase above 68.Bouraoui *et al.* (2002) clarified that a part of the adverse effects of heat stress on milk production could be justified by reduced nutrient intake and decreased nutrient uptake by the portal drained viscera of the cow. Blood stream moved to peripheral tissues for cooling function may alter nutrient metabolism and contribute to lower milk yield during hot weather. It has been shown that glucose disposal is more noteworthy in heat-stressed on contrasted with thermal neutral pair-fed cows. The outcome of the lessening of hepatic glucose synthesis, the change of glucose turnover and the expanded glucose need for energy demand is the lower accessibility of glucose for mammary gland lactose synthesis. Since, lactose production is the essential osmoregulator and according lydecisive of milk yield, decrease of glucose accessibility prompts the lessening of milk yield (Baumgard & Rhoads, 2007).Substantially lower thresholds in our study for THI could be attributed to the reduced adaptability of Iran Holstein cows to heat stress scenarios.

The fat yield was significantly lower (P<0.001) at 70 ≤ THI and THI≤50 compared with 50≤THI ≤70 (Table 1). Dairy cows in 40≤THI ≤50 had less fat percentage than other classes of THI. The protein yield stended to be significantly lower in THI ≥60 compared with 40≤THI≤60. Overall, the protein yields were significantly higher for the lower levels of THI. Our findings of protein yields were consistent with those

Table 1. Fat and protein yields, fat and protein percentage and SCS for temperature-humidity index (THI) classes averaged for the last 3-d preceding the measurement (LSM±SEM).

Variable	Class	Trait					
		Fat percentage	Fat yield	Milk yield	Protein percentage	Protein yield	SCS
DIM	Early	3.13+/-0.04^{a}	1.10+/-0.01^{a}	33.56+/-0.27^{a}	3.13+/-0.01^{a}	1.12+/-0.01^{a}	3.31+/-0.04^{a}
	Middle	3.15+/-0.04^{a}	1.03+/-0.01^{b}	32.41+/-0.27^{b}	3.16+/-0.01^{b}	1.07+/-0.01^{b}	3.19+/-0.04^{b}
	Late	3.27+/-0.04^{b}	0.87+/-0.01^{c}	26.80+/-0.27^{c}	3.27+/-0.01^{C}	0.92+/-0.01^{a}	3.25+/-0.04^{a}
THI	40-50	2.94+/-0.04^{a}	0.98+/-0.01^{a}	32.67+/-0.28^{a}	3.19+/-0.01^{a}	1.08+/-0.01^{a}	3.02+/-0.04^{a}
	50-60	3.2+/-0.04^{b}	1.06+/-0.01^{b}	32.11+/-0.27^{a}	3.23+/-0.01^{b}	1.08+/-0.01^{a}	3.27+/-0.04^{b}
	60-70	3.28+/-0.04^{c}	1.07+/-0.01^{b}	30.26+/-0.27^{b}	3.24+/-0.01^{c}	1.04+/-0.01^{c}	3.36+/-0.04^{c}
	70-80	3.24+/-0.04^{c}	0.96+/-0.01^{c}	30.66+/-0.27^{b}	3.17+/-0.01^{a}	1.01+/-0.01^{d}	3.41+/-0.04^{d}
	≥ 80	3.24+/-0.04^{c}	0.93+/-0.01^{d}	28.93+/-0.27^{d}	3.11+/-0.01^{e}	0.97+/-0.01^{e}	3.21+/-0.04^{e}

Means within a column that do not have a common superscript are significantly different (P < 0.001).

indicated by Rodriguez *et al.* (1985) and Knapp and Grummer (1991) which report a declined milk protein with increased maximum daily temperature. The decrease in milk protein is most likely caused by a declined DMI and energy intake. Declined levels of food intake during lactation are usually related with decreased protein content (Emrey, 1978).Cows in THI ≤60 had the greatest amounts of protein percentage (P<0.05).For SCS, contrasting results between all pairs of THI classes were observed. Totally, SCS increased with THI except for THI≥ 80 approving the trends already reported by others which show negative effects of increased THI on SCC through impaired mammary defense mechanisms (Collier *et al.*, 1982; Du Preez *et al.*, 1990; Muller *et al.*, 1994). In the present study the highest values for SCS were recorded for 60≤THI ≤80.

Output of the regression analysis at three different stages of lactation is given in Table 2. Regarding the lactation status, the highest declines in milk yield related with THI values were accrued in the early lactation (0 to 100 DIM). Similarly to milk yield, the fat yield was negatively associated with the THI in a way that the highest rates were calculated in middle-lactating dairy. Unlike to other traits, SCS was positively associated with the THI and increased more in early period of lactation.

Table 2. Linear regression coefficients between temperature humidity index and fat, and protein yields, fat, and protein percentage and SCS at different stages of lactation (early: 0–100 DIM; mid: 101–200 DIM; late 201–305 DIM).

Trait	Stages of lactation		
	Early (0-100 DIM)	Middle (101-200 DIM)	Late (2-1-305 DIM)
Fat percentage	0.002	-0.002	-0.005
Fat yield (kg/day)	-0.004	-0.004	-0.003
Protein yield	-0.005	-0.004	-0.001
Protein percentage (kg/day)	-0.004	-0.003	-0.005
Milk yield	-0.144	-0.111	-0.012
SCS	0.0003^{ns}	0.003	0.006

ns: Notsignificant (P<0.05)

3.2 Lactation stage

Days in milk had a significant effect on mean milk yield (P<0.0001). Mean milk yield by DIM categories, demonstrated curvilinear relationships (Figure 1) which was higher (P <0.0001) during the first 100DIM compared with all other DIM categories (Table 1).

Results showed a positive relationship of protein percentage and a negative relationship of protein yield with DIM, (Figure 2 and 3). Milk protein percentage increased by DIM and reached minimum value during the first part of lactation (day 52) followed by an increase over the middle part and reached maximum during the late part of the lactation (day 304). Whereas, PY had its maximum value between 1 and 100 d of lactation (day 83), followed by a decrease during the mid-part of lactation and reached minimum over the late part of lactation days (day 305).

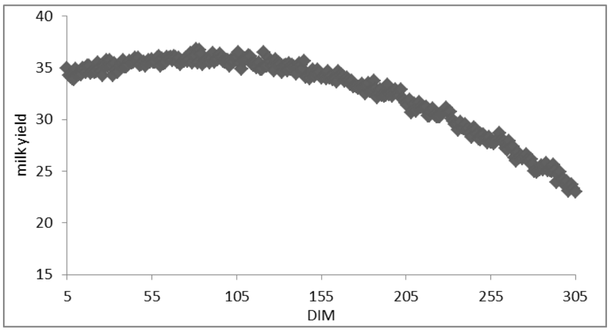

Figure 1. Relationship between milk yield and days in milk (DIM).

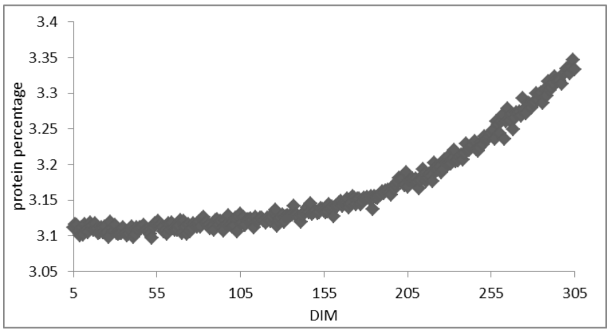

Figure 2. Relationship between protein percentage and days in milk (DIM).

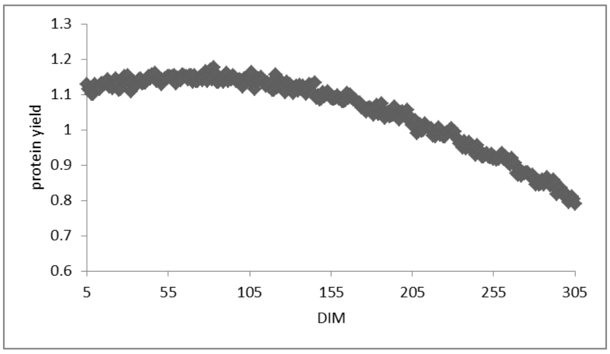

Figure 3.Relationship between protein yield and days in milk (DIM).

Results showed that the effect of DIM on fat yield and fat percentage was significant in a way that as days in milk increased, fat yield was reduced (Figure 4 and 5). Early period (Day 5) registered the greatest fat yield while less production was recorded in the late period (301 days).The results showed that with the elapse of days in milk fat percentage increased, so that the values decreased with days and fell to the lowest value in the mid-term (149 days) and then increased again during the late days and reached maximum on Day 305. No significant difference was found between early and middle classes of DIM for fat percentage while the late class was significantly distinguished from both other classes. Somatic cell count (SCC) values for 3 different stages of lactation differed significantly (P<0.001). Maximum values of SCS observed for the first and late part of the lactation stages (Table 1, Figure 6). Ikonen *et al.* (2004) have shown that SCC was high at the beginning of the lactation period, then decreased stably and fell to minimal level at

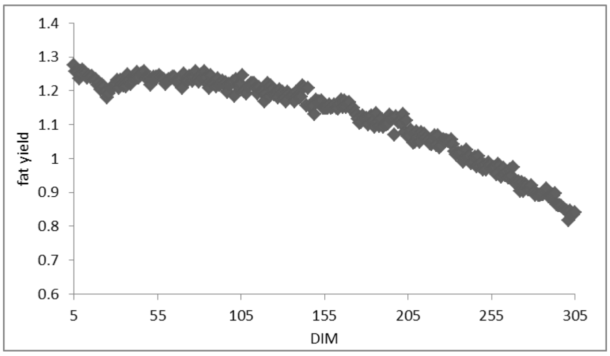

Figure 4. Relationship between fat yield and days in milk (DIM).

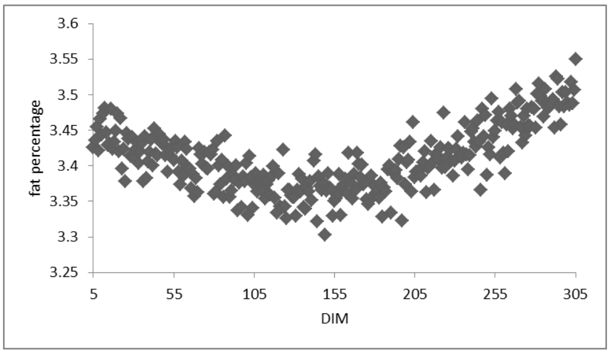

Figure 5. Relationship between fat percentage and days in milk (DIM).

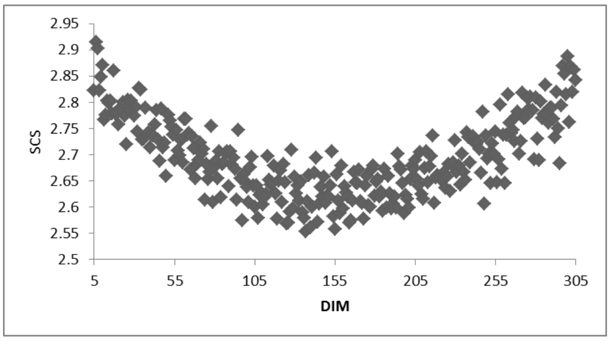

Figure 6. Relationship between somatic cell score (SCS) and days in milk (DIM).

second month and increased thereafter, therefor, reaching maximum level at the end of the lactation. Conversely, Uzmay *et al.* (2003) demonstrated that lactation stage did not affect SCC. In addition, our findings were in agreement with those reported by Miller *et al.* (2004), who reported that correlation coefficients among SCC resulted from 10 different stages of lactation were the highest for adjacent teat days and decreased when the distance of stages of lactation were increased.

4. Conclusions

The results of the present study indicated that THI had significant effect on all studied traits. The greatest milk yields were registered in THI≤60. Unlike to other traits, SCS was positively associated with the THI and increased more in early period of lactation.

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