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Impact of thermal-humidity index on milk yield under conditions of different dairy management

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ABSTRACT

The study aimed to evaluate the effect of elevated temperature on milk production of dairy cows in southern Slovakia in the year 2003. The hypotheses that milk yield is influenced by the stage (peak, midlactation and late lactation), cooling (fogger+fan or fan), and breed (Slovakian Pied cattle and Black-and-White Holstein were tested. Production data included 47,600 test-day records belonging to 16 herds situated in lowlands. During the period from May to September, 113 summer and 59 tropical days were recorded, eighty days were with a mean termal humidity index (THI) value above 72.0, on twelve days we recorded mean values above 78.0. Differences between peak stage (S1) and late lactation stage (S3) were significant in all months, between S1 and S2 in March, May, August and November. S2 and S3 differed in April, May, June, September and November. Dairy cows cooled by fans with water foggers produced significantly more milk in June than cows cooled only with forced ventilation (823.5 kg vs 733.20 kg; P<0.05). In all of the months the Black-and-White Holstein breed exhibited higher performance. For whole-year evaluation, all of the differences between months and stages (843.88, 738.51 and 612.39 kg), between coolings (793.38 vs 697.50 kg), and breeds (655.31 kg vs 811.59 kg) were very highly significant. For the period with high temperatures, we found differences among months (P<0.01) and stages (P<0.001), between cooling methods (P<0.01) and breeds (P<0.001). May and August differed statistically (782.06 kg vs 714.00; P<0.01), as did May and September (782.06 kg vs 694.88 kg; P<0.05). The average values of all lactation stages were significantly different (P<0.001). Evaporative-cooled cows produced more milk than non-cooled (794.60 kg vs 709.20 kg) ones, and the Black-and-White Holstein breed more than Slovakian Pied cows (814.88 kg vs 667.58 kg). A higher milk yield was recored in April than in October (794.44 kg vs 687.75 kg; P<0.001) and in Black-and-White Holsteins than Slovakian Pied (811.88 kg vs 670.31 kg; P<0.001). Similar results were obtained in the comparison of May with September (782.06 kg vs 694.88 kg; P<0.01).

KEY WORDS: dairy cows, milk yield, heat stress, breed, evaporative cooling

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INTRODUCTION

It is apparent that the performance, well-being, and health of an animal are influenced by biometeorological factors. The most important climatological factors are heat stress during the hot season and the wind-chill factor during the cold season of the year.

Heat stress occurs when a dairy cow's heat load is greater than her capacity to dissipate the heat. Critical temperatures will vary depending on several factors including degree of acclimatization, rate of production, pregnancy status, body weight, exposed body surface, hair coat, air velocity, relative humidity, sweating, radiant heat and temperature (Aharoni et al., 2005; Berman, 2005). Life stage, conditioning, and nutritional and health status also influence the level of vulnerability to environmental stressors (Hahn, 1999). Genetic diversity within a population can also influence the level of response and the degree of adaptability, so that what is stressful for some may not be stressful for others.

The welfare of dairy cows can be evaluated as a basis for THI values. In the warming to a critical range of THI of 70-72, performance of dairy cattle is inhibited and cooling becomes desirable. At THI of 72-78, milk production is seriously affected. In the dangerous category at THI of 78-82, performance is severely affected and cooling of the animals becomes essential (Du Prezz et al., 1990). All the adverse effects of the dangerous category are present in the emergency category at THI values of 82 and above, deaths may easily occur and cooling of the animals is absolutely essential (West, 2003). According to the review by Johnson (1987), milk yield starts to decline at mean 72 THI and losses in milk production are clearly related to changes in this factor. Marked declines occur around mean 76-78 THI. Milk yield decreases by 0.26 kg/day for each unit increase in THI. The thermal stress imposed by higher ambient temperatures may be relieved by forced ventilation and by using evaporation of water (Serbester et al., 2005).

The objective of this paper was to evaluate the effect of high temperatures on milk production by dairy cows. We tested the hypothesis that milk yield is influenced by the breed of dairy cows and by cooling.

MATERIAL AND METHODS

The data from test milk records (the first degree of milk performance control) of the State Breeding Institute of Slovakia (all lactations, milk in kg) for all months of the year 2003 were evaluated for a total of 16 herds with 47,600 test-day records. Only records higher than 30 days-in milk and less than 270 days-in milk were taken into account. Three stages were defined: peak stage (30 to 100 days-in milk), midlactation (101 to 180 DIM), late lactation (181 to 270 DIM).

The basic requirements for including a herd were that all selected herds had TMR from good quality components, with a similar nutritive value, feeding twice a day and according to lactation stage. Milk performance had to be on the highest level for the breed under Slovakian conditions during the preceeding year. Herds were allotted into groups according to factors of breed and manner of cooling. The studied cows calved throughout the year.

The meteorological data were recorded continuously at each farm by electronic probes, which were positioned at animal height and connected to a data logger at the Slovakian Bratislava Hydrometeorological Institute. Temperatures (mean, maximum and minimum) and relative humidity's (mean, maximum and minimum) were taken for each hour of the day and each farm separately, and then averages from all herds were calcualted.

The number of summer days (maximum daytime temperature above 25.0ºC) and tropical days according to maximum temperature above 30.0ºC) from 24 h records were determinated. The temperature-humidity index was calculated as proposed by Nienaber et al. (1999) by combining maximum temperature (in °C) and average relative humidity (%) with the following expression: $THI = (0.8 \times T_{max}) + (\% \text{ average } RH/100) \times (T_{max} - 14.4) + 46.4$. THI was calculated for each hour of the day and each farm separately, and then averages of the day (for 24 h) and total average from all herds were calculated.

Breed: 8 herds had Slovakian Pied cows (22,486 records), whereas 8 herds were composed of Black-and-White Holstein (25,114 records). All herds were situated in lowlands, from 130 m to 182 m above sea level.

Cooling: herds were distributed according to cooling of cows during high temperatures. The first group of cows (8 herds) was evaporative cooled twice daily before milking by water spray cooling equipment installed in the holding pen. The fans with water foggers were mounted at a height of 2.5 m and angled downward at about 20º from vertical. The equipment was activated automatically (thermostatically) when the ambient temperature exceeded 24.0ºC and ran continuously as this temperature lasted or unitl milking was terminated. The speed reached the maximum flow rate at 30ºC. Each fan was equipped with circular tubing (diameter 0.56 m, 1420-1500 cycles/min), slightly larger than the fan bell (diameter 0.61 m, 2900-3500 cycles/min), which contained four hollow cone nozzles. Housing and feeding areas were cooled using automatically controlled fans without misting. The forced ventilation systems were activated when the ambient temperature reached 27ºC. The second group of cows (8 herds) was cooled using only forced ventilation (automatically controlled fans without misting in housing and feeding areas).

The feed was a total mixed ration (TMR) consisting of maize silage, lucerne haylage, lucerne hay, barley straw, brewer's grain, sugar-beet pulp and concentrate mixture for high-yielding cows. The TMR was supplied to the troughs by a feeding wagon twice a day during milking. Feeding was allowed throughout the 24-h period, except during milking. TMR was balanced according to Slovakian Nutrient Requirements of Dairy Cattle (Petrikovic and Sommer, 2002). The feed ration included factors for maintenance, growth, reproduction and lactation. TMR was different according to the stage of lactation: early lactation (first four months, calculated milk efficiency of this total mixed diet was 28-32 kg milk), midlactation (5^{th} to 7^{th} month, the calculated milk efficiency of this total mixed diet was 20-27 kg milk), late lactation (calculated milk efficiency of this total mixed diet was 12-19 kg milk).

Individual milk yields were recorded once per month for a morning and evening milking over the period from January to December by Tru-tests. The test interval was not less than 15 or more than 45 days.

The data were analysed using a General Linear Model ANOVA (four ways with the interactions) by the statistical package STATISTIX, Version 8.0 (Anonymous, 2001). The dependent variable was milk yield and the independent variables were month, stage of lactation, method of cooling, and the breed of dairy cows.

The normality of data distribution was evaluated by the Wilk-Shapiro/Rankin Plot procedure. All data conformed to a normal distribution. Significant differences among means were tested by Bonferroni´s (Dunn) method. Values are expressed as means ± standard error of the mean.

RESULTS

The summer of 2003 was extremely hot in East Central Europe and high temperatures already manifested from May and persisted to the end of September. In this period (from May 1 to September 30), there were 113 summer and 59 tropical days (Table 1). The highest temperatures were recorded in August (31 summer days and 22 tropical days). In total, eighty days had a mean value above 72.0. Mean THI of 72 is the point at which heat stress becomes a factor. On twelve days we recorded mean THI values higher than 78.0, which is the dangerous stress category.

Table 1. Climatological parameters during prolonged summer

Index	May	June	July	August	September
SD	19	27	25	31	11
TD	8	15	11	22	3
THI	69.76	73.75	72.08	75.40	69.92
Number of days					
above THI 72	12	18	13	27	10
above THI 78	0	4	2	5	1

High temperatures were also recorded in May and September. It was for this reason that we considered not only the usual June to August period but also the months of May and September as a summer or hot period (Table 2). The course of temperatures, relative humidity and THI (average, minimum and maximum) are shown in Figures 1, 2 and 3.

Table 2. Climatological parameters during period with higher temperatures

Week	Temperature			Relative humidity			THI average	SD/ TD	Dates
	average	min	max	average	min	max			
1	19.3	13.2	26.7	52	28	79	68.69	4/2	1.5.-7.5.
2	20.2	14.0	26.8	65	42	89	71.55	5/2	8.5.-14.5.
3	15.8	8.8	22.3	62	39	87	65.05	2/0	15.5.-21.5
4	20.3	11.6	27.3	64	42	80	72.08	5/3	22.5.-28.5
5	22.3	15.1	28.2	67	43	93	72.99	6/3	29.5.-4.6.
6	26.0	17.1	32.7	59	33	87	78.10	7/7	5.6.-11.6.
7	23.0	15.9	28.7	61	35	90	73.22	6/2	12.6.-18.6.
8	22.0	14.8	7.7	55	32	85	71.48	6/3	19.6.-25.6.
9	23.9	14.0	29.9	47	25	77	73.41	6/2	26.6.-2.7.
10	20.4	14.4	25.7	57	36	80	69.50	5/0	3.7.-9.7.
11	22.1	13.1	28.1	52	30	81	70.77	7/2	10.7.-16.7.
12	25.7	18.3	30.6	60	39	85	74.65	7/4	17.7.-23.7
13	23.4	17.6	27.5	68	48	90	72.57	4/4	24.7.-30.7.
14	24.8	8.1	31.3	63	38	89	76.60	6/6	31.7.-6.8.
15	24.3	14.4	32.0	48	23	78	74.89	7/6	7.8.-13.8.
16	24.3	17.2	32.0	57	32	84	76.11	7/5	14.8.-20.8.
17	23.7	15.1	30.6	48	25	81	74.26	7/4	21.8.-27.8.
18	20.9	13.2	28.2	55	27	72	73.78	4/1	28.8.-3.9.
19	18.6	10.6	25.6	51	31	73	72.73	3/0	4.9.-10.9.
20	18.4	12.8	24.0	58	37	80	70.98	2/0	11.9.-17.9.
21	16.7	10.3	22.0	59	39	76	68.49	6/3	18.9.-24.9.
22	14.8	13.0	20.0	72	40	90	66.35	0/0	25.9.-30.9.

SD = summer day (maximum temperature above 25.0ºC); TD = tropical day (maximum temperature above 30.0ºC); THI = temperature humidity index

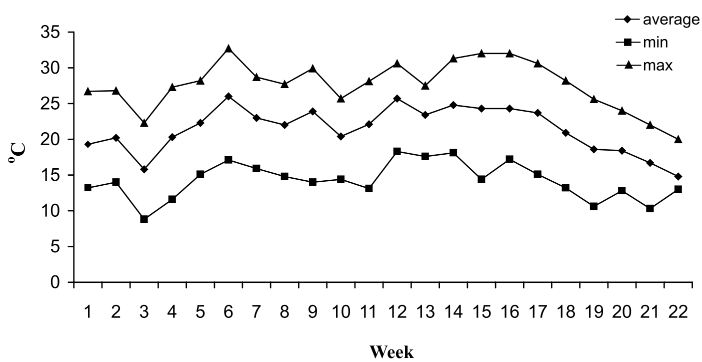

Figure 1. Course of temperatures during individual weeks of period with higher temperature (from May 1 to September 30)

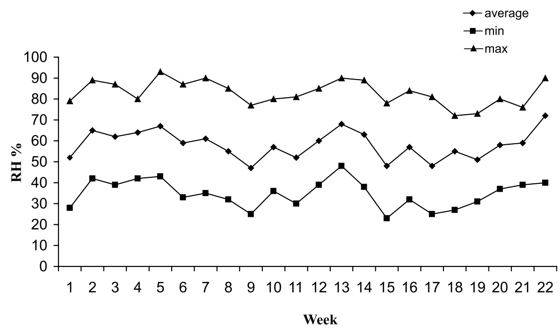

Figure 2. Course of relative humidities during individual weeks of period with higher temperature (from May 1 to September 30)

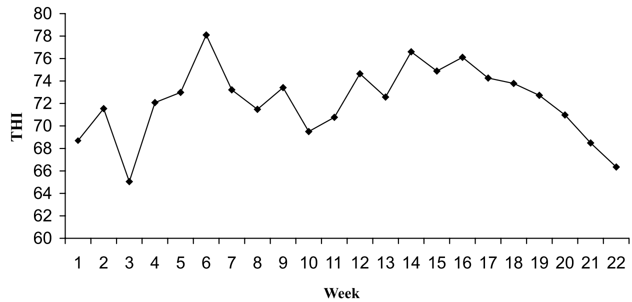

Figure 3. Course of the THI averages during individual weeks of period with higher temperatures (from May 1 to September 30)

Milk production for the entire year according to the individual months (Figure 4) was compared considering stage, cooling (in period with evaporative cooling), and breed (Table 3) as factors. Differences between peak stage (S1)

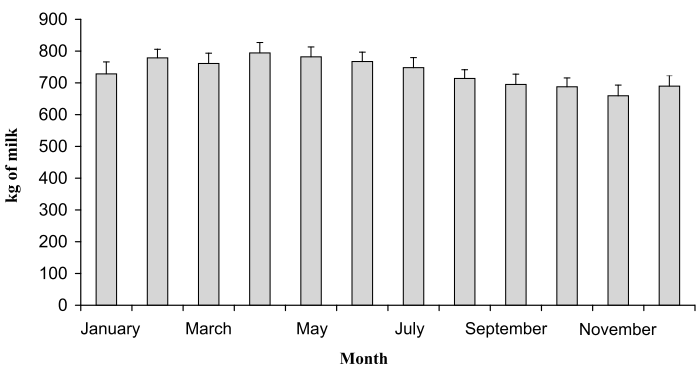

Figure 4. The milk yield during all year

Table 3. The average of milk yield during all year

Month	n	Mean	SE	F-test			
				month	stage	cooling	breed
January	2369	728.25	37.57		4.81* S_1:S_3*		18.10**
February	2715	778.69	27.11		14.80** S_1:S_3**		16.07*
March	3109	761.25	32.26		10.82** S_1:S_3** S_1:S_2*		NS
April	3334	794.44	32.60		18.70*** S_1:S_3*** S_2:S_3**		21.087***
May	3587	782.06	30.95		21.14** S_1:S_2,S_3** S_2:S_3*	NS	32.33**
June	3860	767.06	29.61		10.82** S_1:S_3** S_2:S_3*	5.39*	8.54*
July	4126	748.13	31.44		6.38* S_1:S_3*	NS	6.93*
August	4544	714.00	27.47		17.96** S_1:S_2,S_3**	NS	12.17*
September	4860	694.88	32.47		32.17*** S_1,S_2:S_3***	NS	14.03**
October	4985	687.75	28.02		18.89*** S_1:S_3***		17.45**
November	4973	659.63	33.41		17.19*** S_1:S_3*** S_1:S_2** S_2:S_3*		8.71*
December	4869	689.80	32.52		5.83* S_1:S_3*		NS
Total	47600	733.45	9.29	7.53***	90.53*** S_1:S_2*** S_1:S_3*** S_2:S_3***	14.43***	135.89***

*P<0.05, **P<0.01, ***P<0.001

SEM - standard error of the mean

S1 - peak stage (30 to 100 days-in milk); S2 - midlactation (101 to 180 days-in milk); S3 - late lactation 181 to 270 days-in milk)

and late lactation stage (S3) were significant in all months, between S1 and S2 in March (901.20 vs 760.50 kg), May (881.00 vs 783.00 kg), August (797.50 vs 705.00 kg) and November (825.75 vs 655.29 kg). S2 and S3 differed in April (797.00 vs

668.40 kg), May (783.00 vs 662.40 kg), June (797.40 vs 619.50 kg), September (717.60 vs 587.57 kg) and November (655.29 vs 532.80 kg).

Dairy cows cooled by fans with water foggers produced significantly more milk in June than dairy cows cooled with only forced ventilation (823.5 kg vs 733.20 kg; $P<0.05$).

Higher performance was found in the Black-and-White Holstein in all months, the differences between this breed and Slovakian Pied cattle was very highly significant ($P<0.001$) in April (874.50 vs 714.38 kg) and highly significant ($P<0.01$) in January, May, September and October (845.63 vs 610.88 kg; 859.13 vs 705.00 kg; 772.56 vs 617.25 kg; 749.25 vs 626.25 kg). Also in February, June, July, August and November were differences significant ($P<0.05$) (841.88 vs 715.50 kg; 837.00 vs 697.13 kg; 819.75 vs 676.50 kg; 786.00 ± vs 642.00 kg; 747.75 vs 571.50 kg).

For whole-year evaluation, there were very highly significant differences among all months and stages (843.88, 738.51 kg, 612.39 kg), and between coolings (793.38 vs 697.50 kg) and breeds (655.31 vs 811.59 kg) (Table 3). However, we did not find any significant interactions (month × stage, P=0.2216; month × cooling, P=0.9060; month×breed, P=0.8032; stage×cooling, P=0.7462; stage × breed, P=0.8754; cooling × breed, P=0.6189).

The course of the period with high temperatures (Table 4) is shown according individual factors in Figures 5, 6 and 7. For this five-month period, we found

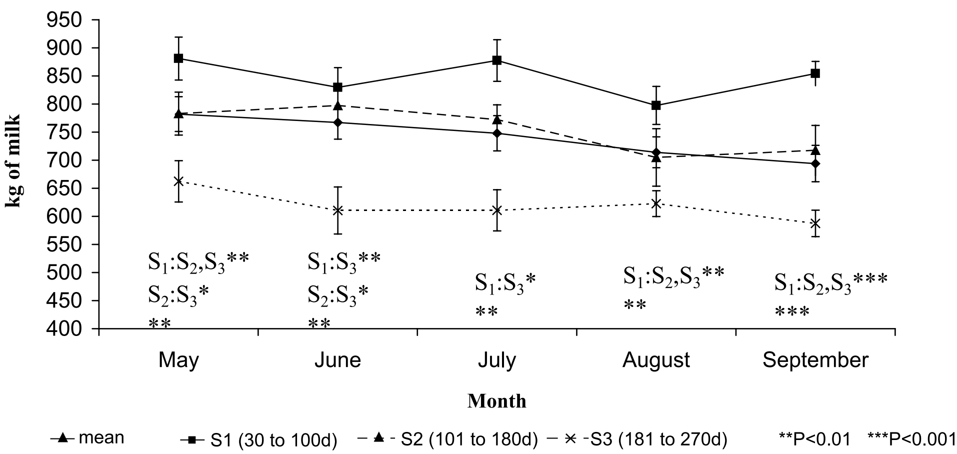

Figure 5. Effect of stage on milk yield

differences among months ($P<0.01$) and stages ($P<0.001$), between cooling methods ($P<0.01$) and breeds ($P<0.001$) (Table 4). Statistical differences were found between May and August (782.06 vs 714.00 kg; $P<0.01$) and May and

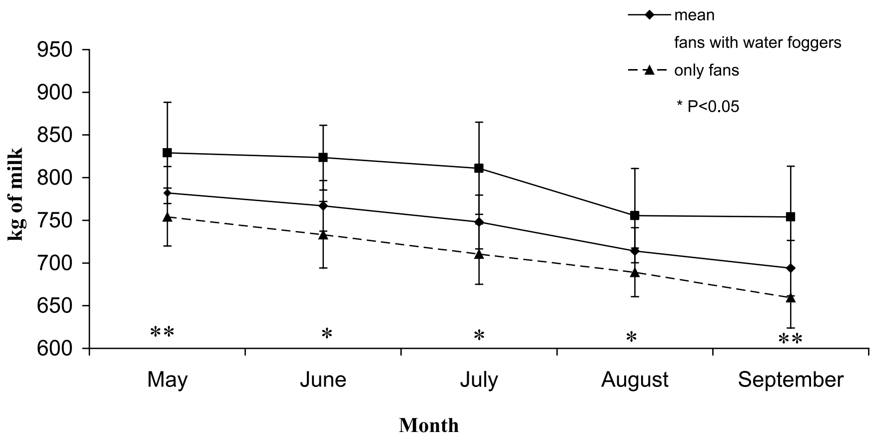

Figure 6. Effect of cooling methods on milk yield

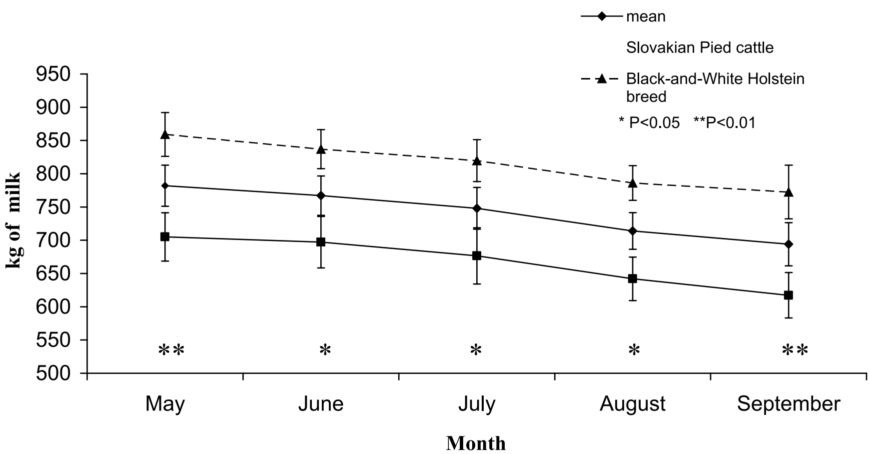

Figure 7. Effect of breed on milk yield

Table 4. Evaluation of all hot period from May to September

n	Stage	Mean	SE	F-test			
				month	stage	cooling	breed
6997	1	844.67	15.99	M:A**	S_1:S_2^{***}		
6660	2	756.33	16.97	M:Se*	S_1:S_3^{***}		
					S_2:S_3^{***}		
7320	3	618.12	13.89				
Total 20977		741.23	13.76	4.77**	57.64***	11.71**	75.70***

M - May, A - August, Se - September

*P<0.05; **P<0.01; ***P<0.001

SEM - standard error of the mean

S1 - peak stage (30 to 100 days-in milk); S2 - midlactation (101 to 180 days-in milk); S3 - late lactation 181 to 270 days-in milk)

September (782.06 vs 694.88 kg; P<0.05). The average values of all lactation stages were significantly different (P<0.001). Evaporative-cooled cows milked out more than the second group (794.60 vs 709.20 kg), and the Black-and-White Holstein breed more than the Slovakian Pied breed (814.88 vs 667.58 kg).

Another evaluation of the period with high temperatures is given in Table 5. We compared milk production in the same stages of lactation only. Dairy cows of the peak stage (S1) differed in the method of cooling. Evaporative-cooled cows produced 879.80 kg milk and cows cooled only with fans milked 800.75 kg (P<0.05). The milk yield was higher in the Black-and-White Holstein breed than Slovakian Pied breed in all three stages (902.14 kg vs 782.77 kg, P<0.001; 800.50 kg vs 668.00, P<0.01; 694.50 kg vs 584.17 kg, P<0.001).

Table 5. Comparison of milk yield in the same stage during hot period

n	Mean	SE	F-test		
			month	cooling	breed
Stage 1					
6997	844.67	15.99	3.15	7.13*	27.37***
			0.0589	0.0218	0.0003
Stage 2					
6660	756.33	16.97	2.94	0.37	19.43**
			0.0707	0.5569	0.0011
Stage 3					
7320	618.12	13.89	2.06	4.03	36.86***
			0.1547	0.0699	0.0001

*P<0.05, **P<0.01, ***P<0.001

SEM - standard error of the mean

S1 - peak stage (30 to 100 days-in milk); S2 - mid lactation (101 to 180 days-in milk); S3 - late lactation 181 to 270 days-in milk)

If we compared the milk yield in the peak stage (S1) only (Table 6), we failed to find any statistical differences among months. However, decreases in June and August (May 811.00 kg, June 771.00 kg, July 823.50 kg, August 737.00 kg,

Table 6. Comparison of milk yield in the first stage in breeds

	Mean	SE	F-test	
			month	cooling
Slovak				
Pied	782.77	17.56	2.85	23.70**
			0.1080	0.0018
Holstein				
4026			1.68	3.17
	902.14	13.94	0.2465	0.1131

September 801.00 kg) are showed on Figure 5. The differences between evaporative-cooled cows and cows cooled with only a fan (832.00 vs 740.57 kg; P<0.01) were high and significant only in June (Figure 6).

The comparison of milk yield in months with similar lengths of daylight (Table 7) is divided into April October (three factors) and May September (four factors). Milk yield was higher in April than in October (794.44 vs 687.75 kg; P<0.001) and in Black-and-White Holstein cows than in Slovakian Pied cattle (811.88 vs 670.31 kg; P<0.001). Means of each lactation stage showed significant differences (P<0.001 or P<0.01).

Table 7. Comparison of milk yield in months with similar length of daily light

n	Stage	Mean	SE	F-test			
				month	stage	cooling	breed
April vs October							
3301	1	843.82	34.58	31.58***	35.36***		37.83***
2487	2	751.20	31.61		S_1:S_2,S_3*** S_2:S_3**		
2531	3	629.18	22.56				
total 8319		741.09	23.21				
May vs September							
2667	1	870.30	23.81	14.78**	42.65***	4.47*	50.38***
2660	2	750.30	29.62				
3120	3	618.75	22.47		S_1:S_2*** S_1:S_3*** S_2:S_3***		
Total 8447		738.47	23.41				

Similar results came from the comparison of May and September. Milk yield per May was higher than per September (782.06 vs 694.88 kg; P<0.01). Also, the mean of each lactation stage varied significantly (P<0.001). During these months (May and September) fans and foggers operated, therefore evaporative cooled cows produced more (791.50 kg) than cows cooled only by fan (706.65 kg; P<0.05). Milk yield was higher in Black-and-White Holsteins than Slovakian Pied cattle (815.81 vs 661.13 kg; P<0.001). We did not find significant interactions between factors of breed and cooling.

DISCUSSION

The average temperature of the Earth's surface is steadily increasing. In East Central Europe the two the hottest years recently were 1998 and 2003. The longest hot summer period was also in 2003. This may be related to global warming.

In the present study, differences among lactation stages were significant in all months. It is obvious that changes in milk yield of dairy cows during high temperatures depend strongly on the stage of lactation. The effects of the ambient environment on a cow's performance have been measured by establishing critical ambient temperatures for the cow (Berman et al., 1985; Igono et al., 1992) and by the temperature-humidity index (THI), which incorporates the combined effects of temperature and relative humidity and is more suitable at the present time. Peak lactating dairy cows begin to suffer mild heat stress at a THI of 72 (West et al., 2003). However, Figure 5 in the present study shows that cows in midlactation and late lactation were more adversely affected than cows in peak stage, moreover, in the cows in the peak stage, milk production always increased after decreasing (in June and August). There is probably some compensation, especially in the peak stage. Similarly, Maust et al. (1972) found that the early group was least affected by summer weather and Johnson (1987) wrote that the early cows tended to recover more during the last two months of the summer. In the present study, a possible explanation is that dairy cows in the peak lactation stage positively responded to the evaporative cooling. Water foggers enhance evaporative cooling or transfer of the heat that an animal produces or absorbs from the environment. According to Johnson (1986), sprays do not alter critical temperatures but allow the animal to better control body temperature, and thus moderate the decline in milk production. According to Kadzere et al. (2002), the point on the lactation curve at which the cow experiences heat stress is also important for the milk yield. On the other hand, cows are less able to cope with heat stress during early lactation. Climatic conditions appeared to have maximum influence during the first 60 days of lactation. High-producing cows are in negative energy balance and make up for the deficit by mobilizing body reserves.

In the present study, higher performance was found in Black-and-White Holstein than in Slovakian Pied cattle. However, from the present study it is clear that these breeds are equally sensitive to the same heat load (Figure 7).

Differences in the milk performance of individual breeds are known. It is well documented that European breeds of dairy cattle are adaptable to cold but are sensitive to hyperthermal stress (Broucek et al., 1998). Igono et al. (1985) found differences in milk yield of dairy breeds (Holstein or Guernsey) during summer; we found a more distinct difference between Holstein and Slovak Pied cattle (dual-purpose cattle). Rodriquez et al. (1985) compared milk production of five dairy cattle breeds. Yields of the Holsteins seemed more sensitive to climatic variation than of Jerseys. However, there is little comparative data for dairy and dual-purpose breeds in reaction to high temperatures that we could consider. According to Johnson (1987), the upper critical temperature for milk production for Holsteins is 21ºC.

Our other purpose was to examine how much the type of cooling could affect milk yield. However, various factors might account for the observed differences. From the data it is apparent that during the year the distribution of mean THI values and its practical implications for lactating dairy cattle are characterized by progressive expansion of heat stress from May, peaking August. Reduced milk production is the recognized result. In the present work, evaporative-cooled cows milked out more than the other group. Dairy cows cooled by fans with water foggers produced significantly more milk in June than dairy cows cooled only by forced ventilation (823.5 vs 733.20 kg; $P<0.05$). High and statistically significant differences were also found between evaporative-cooled cows and cows cooled only by fan in all hot periods.

Considering the obtained results we think that there is a possibility of further reduction of the negative effects of heat stress by extending the treatment to the resting and feeding areas and reducing the time spent standing in the holding pen. Another factor was that the cows were fed twice daily in all observed farms. However, it would probably be better to shift the feedings to times when the air is cooler.

If we compared milk production in the same stages of lactation only, dairy cows of the peak stage significantly differed in the method of cooling. Evaporative-cooled cows produced more milk than cows cooled only by fan. Heat stress in the fresh cow may impair health, decrease milk yield, and lengthen time to peak milk production and peak feed intake. Obviously these reductions of milk yield, as a consequence of the stress, can change in relation to many other factors, in particular to the milk yield level and to the lactation phase. Dairy cattle are adaptable and well suited to a wide range of climatic conditions. However, high environmental temperatures, which come suddenly, and lack of prior conditioning to those temperatures can result in significant losses for dairy husbandry. The drop in milk production in the summer causes significant economic losses in the dairy industry. That decrease in production is brought on by heat stress, and studies have documented that cooling lactating cows increases their milk production (Igono et al., 1985; Kadzere et al., 2002; West, 2003).

Why did higher milk production occur in the spring? Dairy cows calved in the winter and in the spring yielded the most milk, while dairy cows calved in the summer the least (Strabel, 2004; Broucek et al., 2005). Under Mediterranean climatic conditions, summer calvers produce less milk per lactation than winter calvers (Barash et al., 1996). According to Maltz et al. (2000), the summer calving cows attained minimal body weight sooner than winter calving cows. They suppose that the negative energy balance during the summer modified the homeorhetic mechanism so that in comparison with winter calving cows, more nutrients are diverted for repletion of body reserve on the account of their flow to the udder.

Traditionally, the effect of calving season on milk yield is manifested in a difference in nutrition and feeding. A feed ration of a higher quality in the summer should result in high production comparable to that of the winter period. However, this should not be necessary provided the mixed feed ration is balanced and stable throughout the year. In the present experiment, cows could be influenced by seasonal environment such as humidity and temperature, but not by feeding.

Comparison of milk yield in months with similar lengths of daylight showed that milk yield in April was higher than in October. A similar result was obtained in the May and September evaluation. Data of Aharoni et al. (1999, 2002) confirm that a long photoperiod increases milk yield of lactating cows. This increase in milk yield is associated with a significant elevation of an endocrine mechanism for galactopoietic effects. It is also possible that dairy cows calved in the period from December to April would reach a higher average production during lactation, particularly due to the effect of higher persistence of the lactation curve.

CONCLUSIONS

It can be concluded that heat stress can cause significant production- and, obviously, economic losses on commercial dairy farms. In particular, the milk yield reduction, both in unconditioned and conditioned environments, is in a close relationship with maximum daily temperature. Therefore, appropriate housing facilities and equipment to protect dairy cows from climatic extremes have significant importance in maintaining of production. Evaporative cooling combined with air movement is the best protection against high temperature stress.

For protecting dairy cows in East Central European countries against heat stress, several practical minimum precautions have been proposed. However, further research on heat stress in dairy cattle is essential if the dairy industry is determined to achieve more cost-effective milk production, improved herd and udder health. It will probably be necessary to study more closely the functionality, optimal adjustability and spacing of the cooling equipment in barns.

Despite the availability of information on the effects of weather, however, dairy producers still have a real problem in applying that information to usable housing or management for adverse high temperatures.

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