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EFFECT OF HIGH TEMPERATURE ON MILK PRODUCTION OF COWS FROM FREE-STALL HOUSING WITH NATURAL VENTILATION

JAN BROUČEK[1*], PAVEL NOVÁK[2], JITKA VOKŘÁLOVÁ[2], MILOSLAV ŠOCH[3], PETER KIŠAC[1], MICHAL UHRINČAŤ[1]

[1]Animal Production Research Centre Nitra, Slovak Republic, [2]University of Veterinary and Pharmaceutical Sciences, Brno, Czech Republic, [3]University of South Bohemia, Ceske Budejovice, Czech Republic

ABSTRACT

Aim of the present work was to study the influence of high temperatures on milk production of dairy cows. This work tested the hypothesis that the milk yield of Holstein cows kept in open barn is affected by the month, stage of lactation and parity of dairy cows. Following stages were stated in 193 heads: Stage 1, from parturition to 50 d; Stage 2, from 51 to 120 d; Stage 3, from 121to 200 d. Sixty-three summer and 14 tropical days, 86 days with the THI above 72.0, and 26 days with the THI above 78.0, from May to September were recorded. The milk production of dairy cows of Stage 1 was significantly affected by high temperatures for 305 days of lactation than the cows in the Stage 2 (8954.4 kg vs. 9614.1 kg; P<0.05). The monthly milk yields of Stage 1 gradually increased from May to July (from 33.94 kg to 36.62 kg) and started decreasing through August (32.26 kg) to September (30.05 kg). Decrease of milk yield between July and August was significant in Stage 1 (July 36.62 kg vs. August 32.26 kg; P<0.01). Very highly significant differences were found among parities in the index of persistency (P<0.001).

Key words: dairy cow, milk yield, high temperature, lactation stage, parity

INTRODUCTION

The heat stress problem is acutely felt in the East and Central European countries. The weather of these countries is characterized by moderate to high summer temperatures coupled with moderate humidity levels. Hot weather causes heat stress in dairy cows leading to declines in milk production each summer. These declines can be reduced or eliminated by using open barns for optimum milk production. The heat stress problem is getting worse as production levels continue to rise (Mitlöhner et al., 2002; Beatty et al., 2006). The basic condition of management in dairy farms consists in understanding factors that affect milk production mostly, i.e. with the exception of nutrition and dairy cow health status also the parity and season of calving, technological systems, and especially microclimatic conditions (Maust et al., 1972). These factors should be considered not only from the viewpoint of the total milk yield but also from that of the level of milk production, especially the slope of the lactation curve. An important role is played by the stage of lactation - cows in mid lactation are most adversely affected and cows in early lactation the least.

Livestock performance is affected by heat stress because an animal having difficulty in losing heat will decrease its heat production by lowering feed intake (Huber, 1996; Davis et al., 2003; Mader et al., 2004). The upper critical air temperature for lactating cows is in the range of 24 to 27° C (Igono et al., 1992). However, critical temperatures will vary depending on several factors including degree of acclimatization, rate of production, pregnancy status, air movement around the animals and relative humidity (Aharoni et al., 2002; Mader et al., 2006). Cows under a permanent heat stress seem to strike

Correspondence: E-mail: broucek@cvzv.sk
Jan Brouček; Animal Production Research Centre Nitra,
Hlohovecka 2, 941 51 Lužianky, Slovak Republic
Tel. +421 37 6546280, fax: +421 37 6546483

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a new metabolic balance with reduced energy intake and milk production and increased heat dissipation (Kadzere et al., 2002). Life stage, conditioning, and nutritional and health status of animals also influence the level of vulnerability to environmental stressors (Okab et al., 2008).

Daily milk yield was depressed during short-term heat exposure. During the recovery phase, daily milk yield exhibited a further decline (Blackshaw and Blackshaw, 1994; Kadzere et al., 2002). However, according to Broucek (1997), lactating cows that had been exposed to periodic temperature stress showed a regenerative tendency in milk yield during recovery periods. The parity had significant influences on milk production responses during higher temperature conditions (Nardone et al., 1997). There was a large significant difference between the first and second lactation and despite the fact that the maximum milk yield was reached in the fourth lactation it was not significantly different from the mean of the third lactation (Broucek et al. (2007).

The welfare of dairy cows can be evaluated on the basis of the temperature – humidity index (THI) values. This index is commonly used as a practical indicator for the degree of stress on dairy cattle caused by weather conditions (Hahn and Mader, 1997; Bray et al., 1997; Brown-Brandl et al., 2004), because the THI incorporates the effects of both ambient temperature and RH in an index. In the warning to 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, the performance is severely affected and cooling of the animals becomes essential (Huber, 1996). Milk yield starts to decline at 72 mean THI and losses in milk production are clearly related to changes in THI. Marked declines occur around 76-78 mean THI. A decrease in milk yield is 0.26 kg/day for each increase in THI. 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 (Brown-Brandl et al., 2003).

Objective of this paper was to evaluate the effect of high temperatures on production of milk of dairy cows in southern Moravia (Czech Republic, East Central Europe) in the years 2004 to 2006. We supposed that milk production of dairy cows kept in open barn is influence of month, stage of lactation and parity of dairy cows.

MATERIAL AND METHODS

Total of193 Holstein dairy cows were used in the study (1st Lactation – 71 heads, 2nd Lactation – 50 heads, 3rd Lactation – 39 heads, 4th Lactation – 17 heads, and 5th Lactation – 16 heads). The month of calving was the main criterion to select dairy cows. We evaluated data from test milk records, taken at 30-d intervals of the period from December 2004 to May 2006. Three stages were stated according to the days in milk at the beginning of the hottest temperatures – 1st July: Stage 1 (0- 50 d); Stage 2 (51-120 d); Stage 3 (121-200 d). Individual milk yields were recorded by Tru-tests. Cows were milked four times daily during the first 100 days of lactation. Milking was carried out twice daily from 101 day of lactation. Dairy cows were kept in open barn with free-stall housing and external concrete pens.

The total mixed ration was supplied twice daily. Feeding was allowed throughout the 24-hour period, except during milking. The energy content in feed ration for the cows in the Stage 1 was 6.99 MJ NEL/kg DM, in the Stage 2 it was 6.41 MJ NEL/kg DM, and in the Stage 3 it was 5.49 MJ NEL/kg DM. The composition of the TMR remained throughout the year and included corn silage, beet pulp, alfalfa haylage, hay, corn grain, wheat, concentrate mixture, and mineral and energetic components. Feed ration included the factors for maintenance, growth, reproduction and lactation.

The meteorological data were recorded continuously by electronic probes inside the barn (probes were placed at the altitude equal to animal height) and were connected outside to a data logger. The number of summer days (maximum temperature above 25.0 şC) and tropical days according to maximum temperature above 30.0 şC) from 24 h records inside the barn were recorded. Temperature-humidity index was calculated as proposed by Nienaber et al. (1999) by combining maximum temperature (in °C) and average relative humidity (%) per day inside barn with the following expression [(THI = (0.8 x Tmax) + {(% average RH/100) x (Tmax – 14.4)} + 46.4].

The data were analyzed with a statistical package STATISTIX 8. The normal distribution of data was evaluated by Wilk-Shapiro/Rankin Plot procedure. All data confirmed to a normal distribution. Intra-group comparisons for milk production and milk composition for each factor was analyzed using a general linear model ANOVA (General AOV/AOCV). The dependent variables were milk yield, production of milk, FCM, length of lactation and index of persistency, and the independent variables were the factors month, stage and parity. Significant differences among means were tested by Bonferroni's test.

RESULTS

The evaluated summer was extremely hot and high temperatures occurred since May. In July, there were 17 summer and 7 tropical days, while in the August

Table 1: Milk yield during high temperature period (kg of milk)

Stage	n	$\bar{x}$	sx	SE	F test		Interaction
					Stage	Parity	
May							
1	66	33.94	8.99	1.11	33.98^{***}	6.10^{***}	2.53^{*}
2	61	41.55	7.93	1.01	0.0000	0.0001	0.0124
3	66	32.02	6.84	0.84	$S2:S1^{***}$ $S2:S3^{***}$	$P1:P2^{***}$ $P1:P3^{***}$	
Total	193	35.69	8.91	0.64	$S1:S3^{***}$	$P1:P4^{*}$	
June							
1	66	35.95	6.40	0.79	41.43^{***}	5.91^{***}	2.92
2	61	38.20	6.55	0.84	0.0000	0.0002	0.0044
3	66	29.58	6.07	0.75	$S2,S1:S3^{***}$	$P3,P2:P1^{***}$	
Total	193	34.48	7.29	0.52			
July							
1	66	36.62	6.62	0.81	62.44^{***}	4.04^{**}	4.20^{***}
2	61	34.56	5.97	0.76	0.0000	0.0037	0,0001
3	66	27.09	5.67	0.69	$S1,S2:S3^{***}$	$P3,P2:P1^{**}$	
Total	193	32.71	7.35	0.53			
August							
1	66	32.26	5.88	0.72	39.94^{***}	2.08	2.62^{**}
2	61	33.25	6.33	0.81	0.0000	0.0856	0.0097
3	66	25.41	6.29	0.77	$S2,S1:S3^{***}$		
Total	193	30.23	7.07	0.51			
September							
1	66	30.05	5.69	0.70	28.18^{***}	1.11	2.80^{**}
2	61	28.77	5.25	0.67	0.0000	0.3533	0.0060
3	66	23.22	7.01	0.86	$S1,S2:S3^{***}$		
Total	193	27.31	6.72	0.48			
October							
1	66	30.24	6.05	0.74	65.17^{***}	1.30	1.80
2	61	27.69	5.12	0.65	0.0000	0.2724	0.0806
3	66	16.50	8.94	1.10	$S1,S2:S3^{***}$		
Total	193	24.74	9.17	0.66			

$^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$

S1=till 50th day of lactation; S2=from 51 to 120 days of lactation; S3=from 121 to 200 days of lactation; P=parity

23 summer and 6 tropical days. The high temperatures were recorded also in September (11 summer days). We noted 63 summer and 14 tropical days till the end of September in total. Eighty-six days with the THI values above 72.0, which is critical stress category, were recorded. At 26 days we noted values higher then 78.0, which is dangerous stress category.

The average monthly milk yields statistically differed (P<0.001) among lactation stages from May to October, also among parities in May/June and July/August (Table 1, Figure 1). Significant interactions were noted between lactation stage and parity (May, P<0.05; July, P<0.001; August and September, P<0.01).

The average monthly milk yields in Stage 1 were gradually increased from May to July (from 33.94 ± 8.99 kg to 36.62 ± 6.62 kg; Figure 1). The monthly milk yields started decreasing through August (32.26 ± 5.88 kg) to September (30.05 ± 5.69 kg). Differences between months of ascending period (May, June and July) and descending period (August, September and October)

Table 2: Milk performance during lactation (kg of milk)

Stage	n	$\bar{x}$	sx	SE	F test Stage	F test Parity	Interaction
Milk for 305 days							
1	66	8985.4	1526.9	187.94	3.72*	2.26	1.05
2	61	9614.1	1488.6	190.60	0.0262	0.0650	0.4005
3	66	9254.3	1570.6	193.32	S2:S1,S3*		
Total	193	9276.1	1543.5	111.10			
FCM for 305 days							
1	66	8260.4	1305.7	160.72	2.76	2.09	0.97
2	61	8696.8	1350.4	172.89	0.0662	0.0840	0.4608
3	66	8491.6	1460.4	179.77			
Total	193	8477	1378.0	99.23			
Milk for entire lactation							
1	66	10088	2265.4	278.85	1.35	1.76	0.84
2	61	10491	1994.4	255.36	0.2613	0.1384	0.5660
3	66	10186	2374.0	292.22			
Total	193	10249	2217.5	159.62			
Length of entire lactation							
1	66	359.56	67.28	8.28	0.08	1.34	0.46
2	61	350.84	52.71	6.75	0.9209	0.2576	0.8819
3	66	351.85	63.61	7.83			
Total	193	354.17	61.53	4.42			
Index of persistency (P21)							
1	66	87.30	11.15	1.37	0.08	14.89***	1.76
2	61	85.08	10.97	1.40	0.9237	0.0000	0.0885
3	66	87.17	13.52	1.66		P1: P3,P2,P5,P4***	
Total	193	86.55	11.94	0.86			

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

were significant (Table 1). The comparison between July and August is important for an assessment of the effect of high temperature on milk yield. Depression of milk was significant in this Stage 1 (July 36.62 ± 6.62 kg vs. August 32.26 ± 5.88 kg; P<0.01).

Milk yield in Stage 2 was the highest in May, that is, as an immediate response to exposure to high temperature (41.55 ± 7.93 kg), and then it was steadily decreasing until October (27.69 ± 5.12 kg). Differences between May and August, and September and October were highly significant. Milk yield in Stage 3 decreased regularly and slightly with progressing lactation (Figure 2).

Table 2 refers to the milk production of dairy cows in the Stage 1 in July and August were significantly affected by the high temperature for 305 days of lactation more than cows in the Stage 2 (8954.4 ± 1526.9 kg vs. 9614.1 ± 1488.6 kg; P<0.05). Very highly significant differences were noted among parities in the index of persistency (P<0.001).

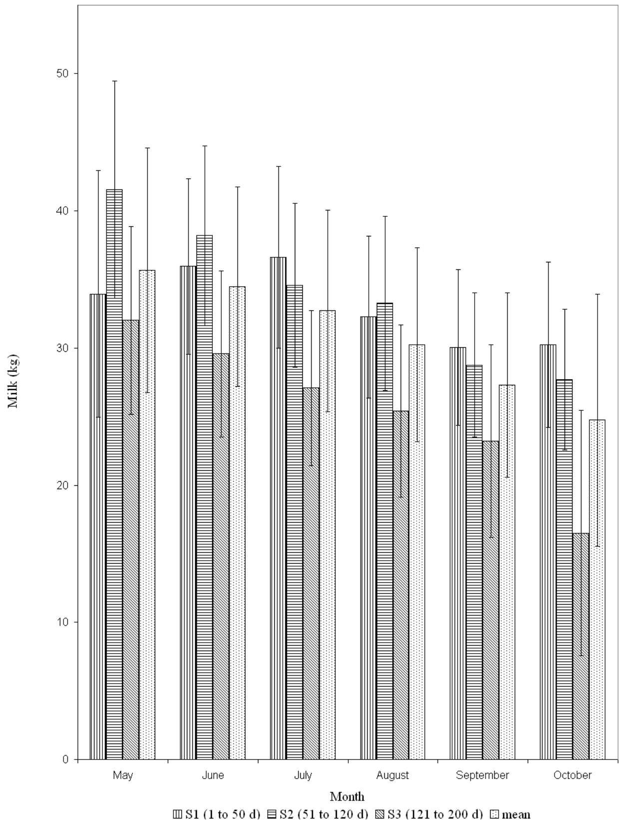

Fig. 1: Effect of the lactation stage on milk yield

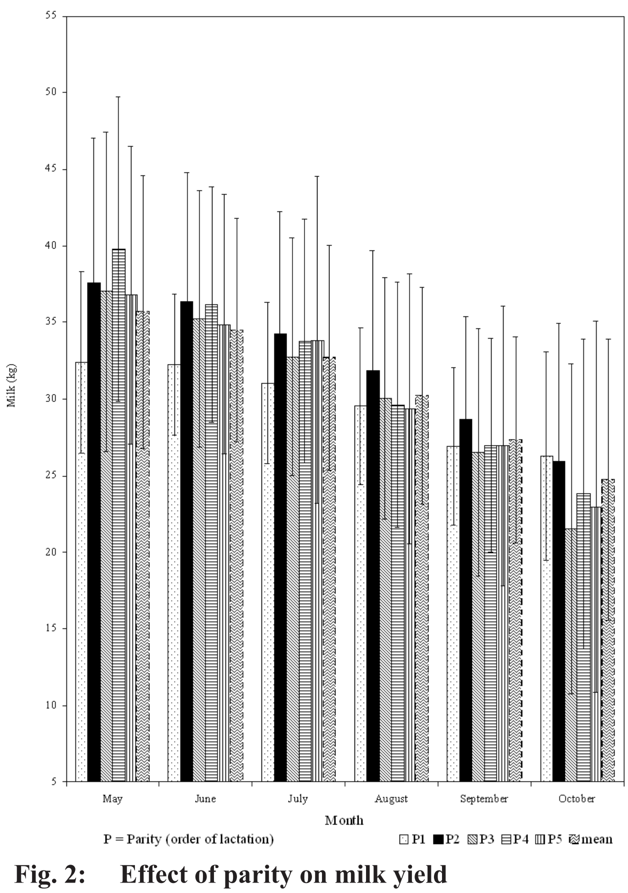

Fig. 2: Effect of parity on milk yield

DISCUSSION

Heat stress (THI) is an important indicator traditionally used for prediction of milk yield during summer. Bucklin and co-workers (1991) suggested that milk production will be reduced whenever THI exceeds a value of 72. Though many studies have examined the effect of heat stress on daily (same day) milk production, other studies suggested a more significant effect a few days after dairy cows are exposed to extreme heat stress (Huber, 1996; Broucek et al., 1997).

High ambient temperatures depressively affect milk production (Igono et al., 1992; Aharoni et al., 1999; Kadzere et al., 2002). However, the effects of hot environment on milk production vary with the stage of lactation. Early lactating cows can be more sensitive to the effect of heat than late lactating cows. The process is associated with maintenance, digestion and metabolism (Robertshaw, 2006; Nardone et al., 2006). Individual variation in lactating yield and shape of the lactation curve under periodic heat stress indicates the possibility of discussing productive adaptation in high performance cattle more deeply from a genetic perspective. There are adverse opinions on this lactation stage effect. Cows in the early stage of lactation extensively utilize body reserves and are less dependent on consumed feed energy. They are on the higher level of production, despite consuming the least feed (Maltz et al., 2000; Broucek et al., 2007).

In the present study, the average monthly milk yields of Stage 1 were found to increase gradually from May to July and then decreased till September. Distinct limit for production of milk was observed between July and August and milk losses during those months were expressive. Milk yield in the Stage 2 was the highest in May and then production gradually decreased until October. This might indicate that cows from Stage 1 were influenced by the hyperthermal stress the most. However, this reduction of the amount of milk yield in our distribution of the year can change in relation to many other factors, in particular to the milk yield level and to the reproduction phase. Johnson (1987) suggested that the average daily losses in milk production for early stage cows were 5.5 kg/day/cow, mid stage 2.6 kg/day/cow, and late stage 2.9 kg/day/cow for the first 55-day period during the summer. Heat stress in the fresh cow may impair health, decrease milk yield, and lengthen time to peak milk production and peak feed intake. However, the early cows tended to recover more during the last 55 days of the summer.

Milk production by of Stage 1 dairy cows was significantly affected by high temperatures for 305 days lactation more than the Stage 2 cows (8954.4 ± 1526.9 kg vs. 9614.1 ± 1488.6 kg; $P<0.05$). The highest milk yield during lactation was noted in cows, which were at the beginning of July on their 51 to 120 days in milk. That means high temperature markedly limited the efficiency of Stage 1 cows. The Stage 2 cows with higher production were probably less sensitive to the effects of high ambient temperatures. This contradicts the findings of Maust et al. (1972) who stated that mid-lactation cows were most adversely influenced by heat stress, whereas those in late lactation were affected fairly and those in early lactation the least. These authors also observed that cows in mid-lactation were most affected, but they seemed to recover from one or more days of thermal stress better than cows in late lactation (Maust et al., 1972). Similarly, the present study noted the lowest milk production during entire lactation in Stage 1 cows, while summer months recorded their peak production (about 50 days); however, the differences were non-significant.

The effects of heat stress may be more pronounced in older cows than first-lactation heifers. In the present study the cows of higher parities were found to be affected most by the high temperatures. Thompson et al. (1999) reported a significant reduction in 305-day milk production of second-lactation or older cows that was not seen in first-lactation heifers. It is a common field observation that heifers don't suffer heat stress to the extent mature cows do. Older cows were more severely affected because they had higher feed consumption and therefore, they digested more, produced more milk, and had more fatty insulation preventing heat loss, as compared to primiparous cows. Keck et al. (2004) indicated that the prevalent climatic conditions on the farms during the day induced stronger thermoregulatory responses in the cows than the conditions that prevailed during the night. However, within the measured range of climatic conditions, the cows were hardly exposed to severe cold or heat stress and thus able to cope with these conditions.

CONCLUSIONS

Milk production of cows is influenced by environmental factors, especially high temperature during summer. Hot weather conditions reduce dry matter intake and level of decrease in milk production is also affected by stage of lactation. Milk production of dairy cows was significantly affected by high temperatures for 305-day lactation in comparison to cows at mid-lactation stage.
It is probably necessary to study the methods of the air-cooling in open barns more closely.

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