The influence of high ambient temperatures in particular stages of lactation on milk production of Holstein dairy cows

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Abstract In dairy cows high ambient temperatures are associated with a decline of milk yield. The extent of milk yield decline observed in heat stressed cows depends on a series of factors. High yielding cows are more sensitive to heat and also stage of lactation affects response of dairy cows to high ambient temperatures. We compare milk production in dairy Holstein cows spending hot summer months in their peak production (about 50 days of lactation), about 100 days, 200 days and 300 days of lactation. The lowest milk yield in 305-d lactation was found in cows spent summer months in their 300-d of lactation, the highest milk production was in cows spending hottest period of the year in their 100 days of lactation (and so calved in spring months).

Introduction

The basic condition of management in dairy farms consists in understanding factors that affect milk production mostly, i.e. the order of pregnancy (year) and season of calving, the order of lactation, technological systems, and microclimatic conditions, the length of the calving interval and dry period, and last but not least nutrition and dairy cow health status. 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 function.

The relationship between the animal and its environment determines the degree to which animal remains in thermal equilibrium with its environment (Finch, 1976). The thermal environment has a strong influence on farm animals with air temperature having primary effect, but altered by wind, precipitation, humidity and radiation (The National Academy of Science, 1981, 2000). The thermal environment is a major factor that negatively affects milk production of dairy cows, especially in animals of high genetic merit (Kadzere et al., 2002).

Lactating dairy cows are the cattle most sensitive to high ambient temperatures. The major challenge for high producing dairy cows in hot climates is to dissipate heat produced by metabolic processes. Metabolic heat production increases as the productive capacity of dairy cows improves. Cows yielding 18,5 and 31,6 kg/d of milk produced 27,3 and 48,5% more heat, respectively, than dry cows (Purwanto et al., 1990). Cows in hot climates generally produce additional heat relative to cool climates because of the greater physical activity (such as panting) necessary to enhance cooling in hot conditions.

Materials and methods

The data for this study are from 284 Holstein dairy cows. Monthly test day milk yields, taken at approximately 30-d intervals, were used to make individual lactation curves. The period September 2002 to August 2004 was considered. The month of calving was the main criterion to select dairy cows, the reason being a possibility to compare the course of lactation curves at a given year season.
Dairy cows were housed in reconstructed three-row freestall barns with opened one long side and natural roof ventilation. Cows had no supplemental cooling from fans or misters. Milking parlour was installed in a separate part of the stable.
Milking was carried out four times daily in the first 100 days of lactation and than twice daily. Standard feed ration (TMR) observing difference energy requirements of the production cow groups were given two times daily. The energy content in feed ration for the cows in the first phase of lactation was 7,05 MJ NEL/kg DM, in the second phase 6,43 MJ NEL/kg DM, and in the third phase 5,48 MJ NEL/kg DM, respectively. The composition of the TMR was relatively constant in the year and includes corn silage, beet pulp, haulage, hay, corn grain, wheat, concentrate mixture, water and mineral and energetic components.
We compare lactation curves, total milk yield in 305-d lactation, total milk yield in 305-d lactation corrected in 4% content of fat and index of persistency of dairy cows. Cows were divided in four groups according their stage of lactation - 50d after calving, 100d after calving, 200d after calving and 300d after calving, when these periods' cows spent in the hottest months in the year - July and August.
The statistical analysis was approved with one-way ANOVA in the statistical program Statistica.Cz.

Results

The highest milk yield in lactation was found in cows when the hottest months in the year (July, August) were in their approximately 100 days in lactation. In their 305-d lactation cows produced in average 9717 kg of milk, in the whole lactation 10595 kg of milk (in 358 days). The lowest milk production was found in cows when the hottest months were in their approximately 300 days of lactation, in the 305-d lactation cows produced in average 8939 kg of milk, in the whole lactation 9724 kg of milk (in average 364 days). The maximum peak production was found in cows with the highest milk production in lactation, analogous the lowest peak production was in cows with the lowest milk production in lactation. The minimum amount of 4% fat corrected milk in 305-d lactation was found in cows when the hottest months were in their peak production (8379 kg). The index of persistency was similar for all groups of cows and was about 85-87.
Results are summarised in Table 1, the statistical values are mentioned in Table 2.
Course of lactation curves is mentioned in Graph 1.

Table 1: The comparison of milk production of dairy cows influenced with high environmental temperatures in particular stages of lactation

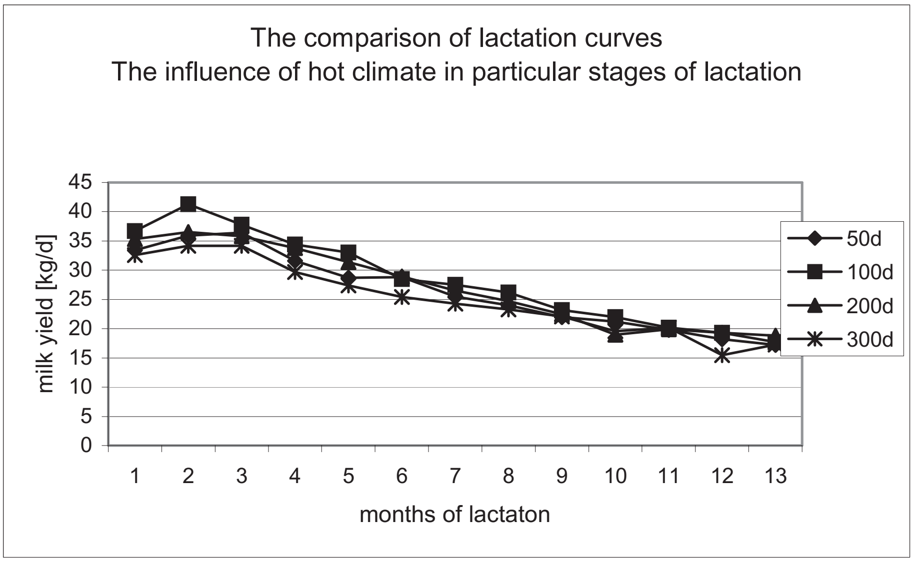
	n	lactation	305-d lac.	FCM-NL	P2:1	days
50d	76	9540	9102	8379	86	348
SD		2626,6	1408,9	1123,2	12,3	77,7
100d	65	10595	9717	8828	85	358
SD		2071,2	1451,9	1254,3	11,8	55,8
200d	75	9812	9464	8768	87	343
SD		2456,7	1448,0	1159,3	12,8	65,5
300d	78	9724	8939	8456	85	364
SD		2319,7	1372,6	1026,6	14,7	74,6

FCM-NL= 4% fat corrected milk in the 305-d lactation

Table 2: Statistical values

	t	F	p	statistical significance
100d - PEAK	2,2528	5,075	0,0260	P < 0,05
100d - 200d	0,9001	0,810	0,3700	
100d - 300d	2,9006	8,414	0,0045	P < 0,01

Graph 1: The comparison of lactation curves of dairy cows influenced with high environmental temperatures in particular stages of lactation



Discussion

Generally, high ambient temperatures depressively affect milk production (Johnson et al., 1961, McDowell et al., 1976, Moody et al., 1967, Shibata, 1983, and so one). Araki et al. (1984) reported that lactating cows were more sensitive to the effect of heat than were nolactating cows, consistent with the greater metabolic heat production. The process associated with maintenance, digestion, activity, metabolism, and production create a large amount of heat. High milk yield requires the intake of large quantities of nutrients and greater heat production.

Relevance of this impact on milk production broadly depend not only on level of milk production but either on stage of lactation. There are different conclusions in this field. On one hand, milk production is more influenced in early-lactation cows and mid-lactation cows because cows are in negative energy balance (the input of energy is lower than output of energy) and the physiologically decrease of DMI is deepened by hyperthermia (Sharma et al., 1983; Thatcher, 1974). On the other hand milk yield in early lactation is strongly supported by tissue stores mobilisation (lipid in particular) and less by feed intake and because metabolic utilisation of tissue stores has a higher efficiency (about 84%) compared to the metabolic utilisation of feed (about 64%), the early lactating cows are expected to produce less metabolic heat per kg of milk yield (Maust et al., 1972). The heat production associated with the use of body tissue stores is approximately one-half of that produced by direct conversion of dietary ME to milk (Coppock, 1985). Johnson et al. (1988) observed that the mid-lactating dairy cows were the most heat sensitive compared to early or late lactating counterparts. Accordingly, studies carried out in climatic chambers described an heat stress related decrease in milk yield of 35% in mid lactating (Nardone et al., 1992), and of 14% in early lactating dairy cows (Lacetera et al., 1996). Variations of nutritional-metabolic conditions during lactation might explain the higher sensitivity to heat stress of mid lactating dairy cows. Mid lactating dairy cows have higher feed intake and still high milk production and so greater production of heat.

In our study, the highest milk yield in lactation was found in cows that summer months coincide with their approximately 100 days of lactation. These cows calve in spring (March, April) and this result correspond with recognition in other part of our study passing of this dairy herd – observation of influence the season of calving on milk production – the highest milk yield in lactation was found in cows calving in spring. Analogous Kučera et al. (1999) found, dairy cows calving from the late autumn to spring produce more milk (up to 8 percent) than those calving in summer. This is likely due to an interaction between day light and ambient temperature. The lowest milk production in lactation and in particular monthly test days was detected in cows spending summer months just about their 300 days of lactation. These dairy cows calved in early autumn and hot summer months coincided with their dry period and late gravidity. According to Collier et al. (1982) heat stress has a persistent effect also in the period of late pregnancy and may negatively influences milk production after calving and in early lactation. Milk yield was considerably reduced not only in early lactation but in the period of whole lactation (4960 kg vs. 6430 kg in colder conditions).

When we compared milk yield corrected in 4% fat content, the lowest value was found in 50-d group (summer months in their peak milk production). Season variations in milk composition are commonly observed with dairy cattle in temperate regions. In general, milk fat and solid-not-fat percentages are highest in winter and lowest in summer. Milk fat and protein percentages are lower by 0.2-0.4% in summer than winter. Cows calving in the fall or winter produce more fat and solid-not-fat than cows calving in the spring and summer (Mustafa, 2001). Consistent with this the lowest milk fat percentages produced cows spending summer period in their 50 and 100 days of lactation, so calving in spring and in beginning of summer and so produce lower amount of FCM. On the other hand, results on the effect of heat stress on milk fat percentages are conflicting (Nardone et al., 1992; Armstrong, 1994) and also there are changes in composition of milk fat. Heat stressed cows had to be attributed to the reduced synthesis of short- and medium-chain fatty acids in the mammary gland cells rather than to a higher incorporation of long-chain fatty acids (Smith et al., 1983). Moreover, it was also suggested that the higher availability of long-chain fatty acids coming from lipomobilization would not hesitate in their higher incorporation into milk because these fatty acids might utilised as energy sources by the mammary gland cells (Smith et al., 1983). Accordingly, Nardone et al. (1997) reported an increase of long-chain and a reduction of short-chain fatty acids also in colostrum yielded by heat stressed heifers. None of these authors attributed changes of milk fatty acids to a direct effect of heat stress, and suggested that they had to be attributed to the higher dietary intake of fat or to the lower forage intake which usually occur during summer, or to a more massive utilisation of body reserves.

Conclusions

Milk production is markedly influenced by environmental factors, mainly ambient temperature. Hot weather conditions reduce dry matter intake and milk yield in dairy cows and level of this decrease of milk production is also affected by stage of lactation. Classical work demonstrated that cows in mid and late lactation were more adversely affected by hot weather compared with early lactation cows, despite greater yield for the early lactation cows (Maust et al., 1972). The higher producing early-lactation cows were probably less sensitive to the effects of high ambient temperatures because of less total DMI and the more efficient use of mobilised body tissue reserves. In our study, we found the lowest milk in 305-d lactation in cows spending summer months in their late lactation (about 300 days of lactation). The lowest milk production in whole lactation was in cows spending summer months in their peak production (about 50 days) because of shorter duration of lactation. This conclusion we associated with impact hot conditions in late pregnancy and still high temperatures in early lactation and moreover impact hot conditions in late lactation.

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