HEAT STRESS IN A MILD CLIMATE: DUTCH EXPERIENCES

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Introduction

The most comfortable environmental temperature range for dairy cows, the thermal comfort zone, is between 5°C and 25°C (Shearer and Beede, 1990a). When environmental temperature is above 25°C for an extended period, an alteration in basal metabolic rate is required in order to maintain normal body temperature. Dairy cows respond to high temperatures by seeking shade and wind, increasing water intake and respiration rate (Shearer and Beede, 1990a; Elvinger et al., 1991; Lacetera et al., 1996). The total body heat production of a cow is a combination of heat derived from normal metabolism, from the environment, and from physical and performance activities, such as milk production. Metabolic consequences of heat stress are increased heart rate (Elvinger et al., 1991), lower plasma glucose levels (Lacetera et al., 1996; Ronchi et al., 1999), changes in the levels of stress hormones (Giesecke, 1985; Collier et al., 1982; Katti et al., 1987) and an increase in rectal temperature (Johnson et al., 1989; Berman et al., 1985, Elvinger et al., 1991, Lacetera et al, 1996; Ronchi et al., 1999). In order to lower body heat production, cows experiencing heat stress will voluntarily reduce dry matter intake, which results in depressed milk production (Johnson et al., 1989; Ronchi et al, 1999; Shearer and

Beede, 1990b; Lacetera et al., 1996). Other factors that may play a role in milk yield decline, associated with heat stress, are changes in hormone levels and an increase in maintenance requirements (Bernabucci and Calamari, 1998; Collier et al., 1982). Generally, these responses decrease short-term animal performance (Shearer and Beede, 1990a).

High temperatures may also affect susceptibility to infection, either by decreasing host resistance or by increasing the exposure to pathogens. Elevated temperature and high relative humidity enhance the survival and proliferation of pathogens in the environment. Under circumstances of heat stress, cows may lie in the alleyways of free stall barns or wallow in ponds, streams and mud holes in pastures, in order to increase heat loss. This behaviour increases the risk of infection (Shearer and Bray, 1995). Increased milk SCC and a higher incidence of clinical mastitis in dairy cattle have been found in cows exposed to a hot environment (Elvinger et al., 1991; Collier et al., 1982).

Evidence for a direct effect of elevated environmental temperature on the immune system is limited (Elvinger et al., 1991; Shearer and Bray, 1995). An indirect effect on immunity may occur as a result of decreased feed intake and, consequently, insufficient uptake of essential nutrients, which are important to optimal immune function (Shearer and Beede, 1990b).

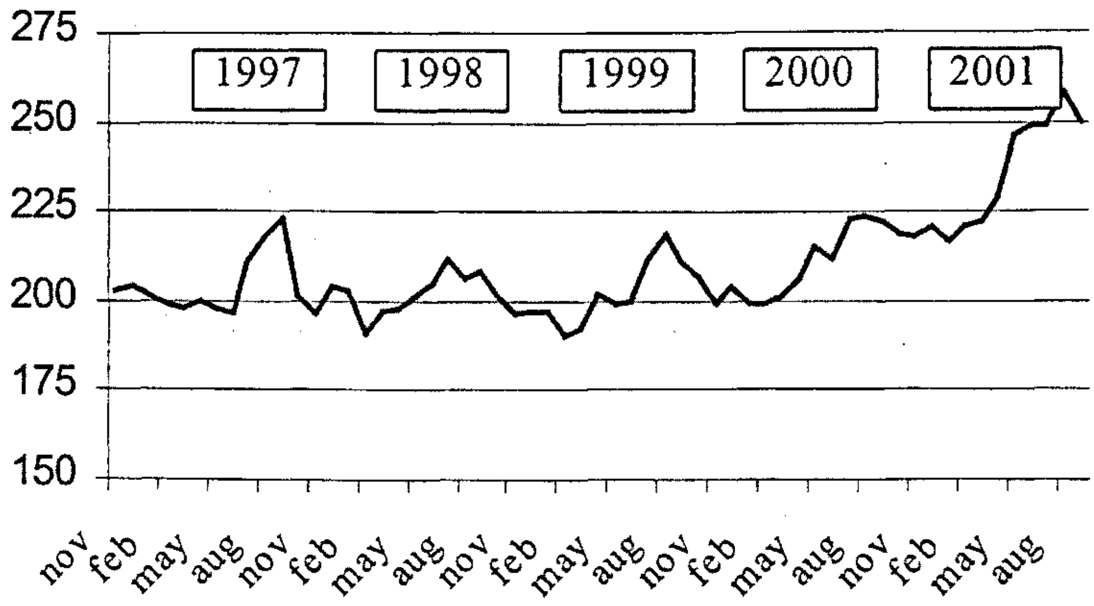

Figure 1. Development of the Dutch bulk milk cell count (arithmetic mean) from november 1997 until september 2001.

Heat or climate stress is a phenomenon commonly associated with extreme climatic circumstances such as in Israel or Arizona. However, mild stress can occur at a temperature of 25°C and a relative humidity of 50% (Armstrong, 1994). These are circumstances that do occur in mild climates such as in the Netherlands. A little more than 5 years ago, in the Netherlands the first signs of occurrence of heat stress were reported from practice. These reports were partly based on the observation that the bulk milk SCC seemed to be higher in summers, whereas the bulk milk SCC used to decrease in summers due to a decreased risk on intramammary infection since cows were grazed outside. Figure 1 illustrates these increases in bulk milk somatic cell count (Dutch arithmetic average) during summers. In summers with longer periods of high temperatures, such as 1997 and 1999, the average bulk milk SCC increased even more than in other, cooler, summers. The bulk milk SCC increased during 2000 and 2001. This is partly caused by a change in the Dutch milk quality scheme. Milk price reduction used to be applied when one bulk milk tank exceeded the limit of 400.000 cells/ml. From 2000 milk price reduction was given when the geometric mean of three monthly taken bulk milk SCC measurements exceeds the limit of 400.000 cells/ml. This means that for part of the farmers the financial motivation to be alert on a high BMSCC is party removed. Part of the exceptional increase in 2001 might be caused by heat stress in the months July and August. Another part might be caused by the exceptional circumstances due to the foot and mouth disease outbreak.

Since the first evidence for the occurrence of heat stress in dairy cattle in the Netherlands, two scientific studies have been carried out to get more insight in the occurrence and background of heat stress in the Netherlands. This paper presents the results of both studies. The objective of the first study was to find statistical evidence for the assumed relation between hot summers and an increased BMSCC. The objective of the second follow-up study was to evaluate dairy cow characteristics that play a role in the cow's reaction to periods with increased environmental temperatures in a mild climate. Both studies have already been published by Sampimon et al. (1999) and Poelarends et al. (2000).

Material and methods

Study 1. Relation between high temperatures and heat stress under mild climatic circumstances

BMSCC and temperature data were obtained for the years 1993, 1994 and 1995. From each year nearly 300.000 BMSCC measurements from 23.325 farms (70 % of all Dutch farms) were available. These measurements came from three large dairy industries. Only days with more than 1.000 measurements were included in the study. Per day the average BMSCC was calculated and regarded as the average Dutch BMSCC at that moment. The temperature data were obtained from a weather station on research farm Aver Heino from the Research Institute for Animal Husbandry in the east of the Netherlands. To reduce the variation, the moving average from three successive days of the maximum temperature was calculated. The average maximum temperature and BMSCC were compared on each date in the years 1993, 1994 and 1995. The years 1994 and 1995 were years with periods of a high summer temperature. The year 1993 was used as a control year.

Study 2. Dairy cow characteristics related to heat stress response

Data of 47 randomly chosen herds, with a total of 1563 dairy cows, that participated in the Dutch milk recording system and measured cow SCC at least every 4 weeks, were used. Data were available for the years 1995 and 1997 with long warm periods during the summer and for the year 1996 with a moderate summer.

The following parameters were available: cow SCC (5 categories with limits 75.000, 150.000, 250.000 and 500.000 cells/ml), milk production (6 categories with limits 15, 20, 25, 30 and 35 kg/day), parity (3 categories with parity 1, parity 2 and 3, and parity ≥ 4) and stage of lactation (6 categories with limits 75, 125, 200, 250 and 300 days in lactation).

To investigate the changes in milk production and SCC during the summer, two four-week periods in every year were defined. Per four-week period, the weighed average SCC was calculated. For all years, the period with the highest average SCC was defined as effect period. The preceding period was defined as the control period. In the years with a warm summer, the effect periods coincide with the higher temperatures, although the defined effect period starts later than the increase in temperature.

The relative changes in cow SCC were calculated by dividing the SCC in the effect period by the SCC in the control period. The relative changes in daily milk production were calculated in a similar manner. The relative changes in SCC were log-transformed to obtain better statistical properties. The milk production index per cow was calculated as follows: milk production of the cow/mean daily milk production of the herd * 100. The milk production index was divided into 5 categories with limits 70%, 90%, 110% and 130%. Effects of parity, stage of lactation, production and year on change in milk production and SCC were estimated using models (1) and (2). The models were fitted with the REML procedure of Genstat (Genstat 5, 1994).

Results

Study 1. Relation between high temperatures and heat stress under mild climatic circumstances

In the year 1993 with no warm periods the BMSCC was stable (Figure 2). In the years with long warm periods, 1994 and 1995, the BMSCC was significantly elevated during these warm periods (Figures 3 and 4). It seemed that the periods with increased BMSCC lasted longer than the warm periods. Although not statistically checked, this could also be noticed from Figure 1.

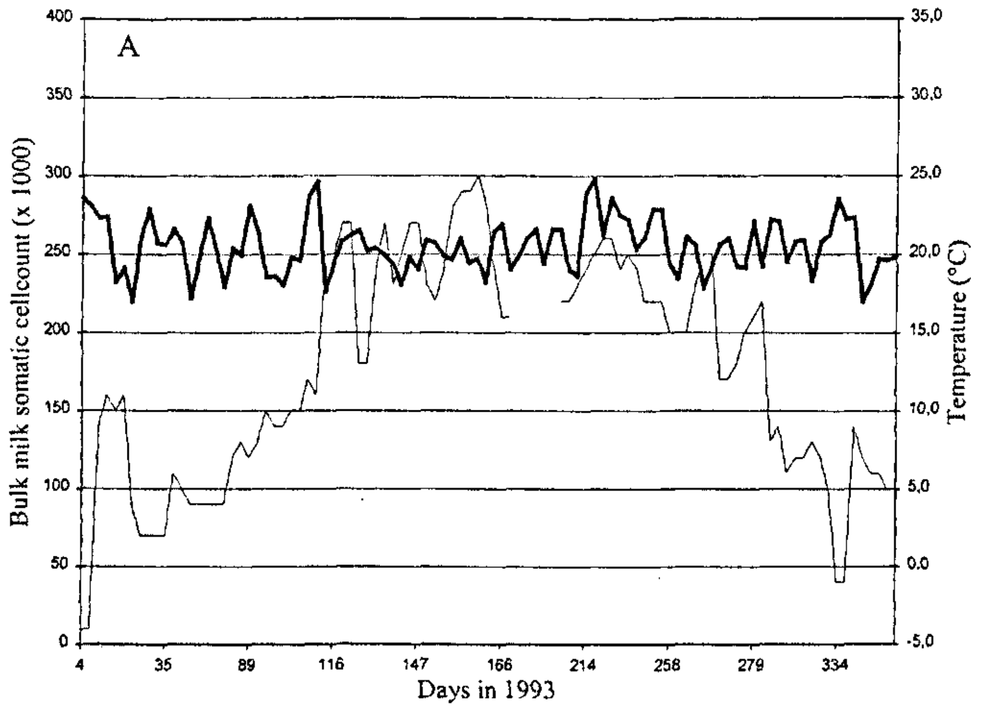

Figure 2. Temperature (lower line) and BMSCC (upper line) for Dutch dairy herds in the year 1993.

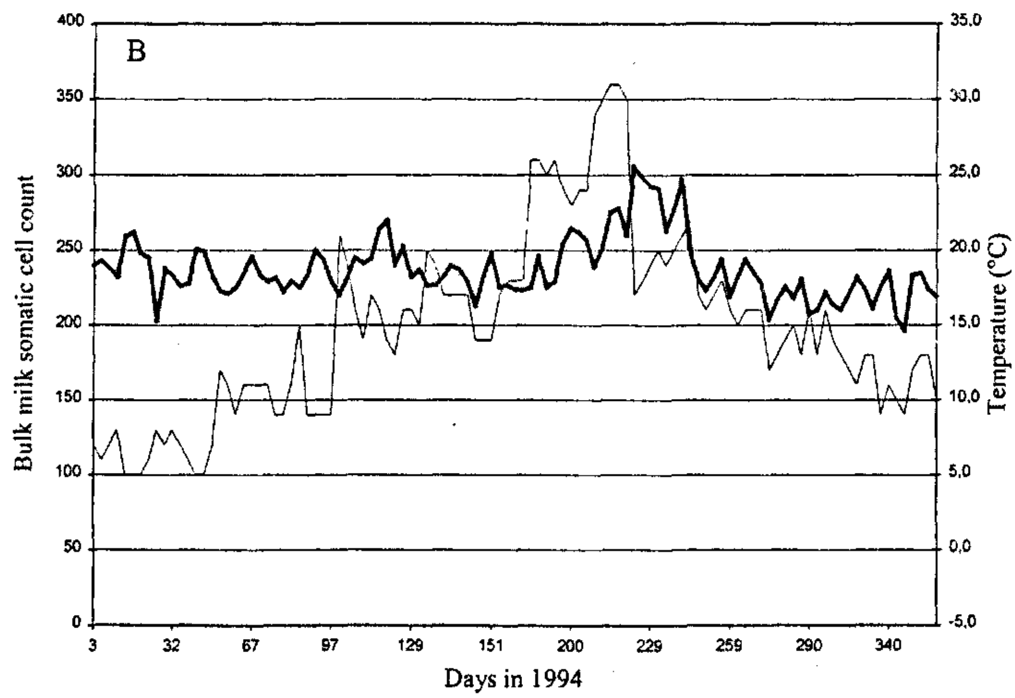

Figure 3. Temperature (— lower line) and BMSCC (▬ upper line) for Dutch dairy herds in the year 1994.

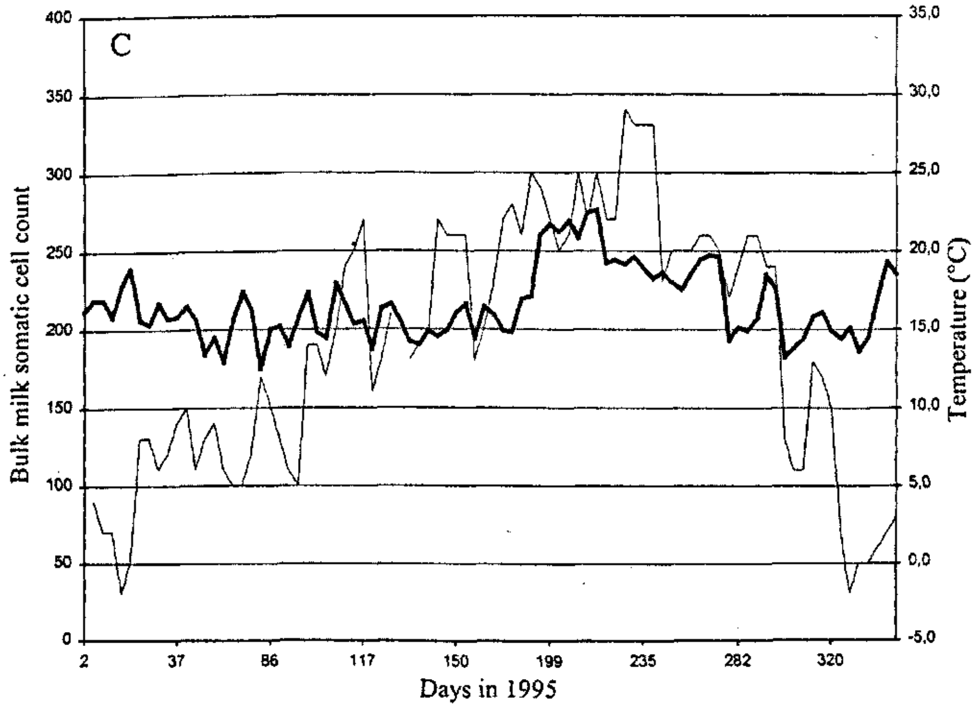

Figure 4. Temperature (— lower line) and BMSCC (**—** upper line) for Dutch dairy herds in the year 1995.

Study 2. Dairy cow characteristics related to heat stress response

In table 1, mean SCC in the effect and control period and changes in SCC both based on the rough data as well as on the statistical model are given per year. Results show that SCC increases in each year. In 1997 the increase in SCC is highest and tends to differ significantly from the increase in 1996, in which the increase is lowest.

Table 1. Mean cow SCC in the control and effect periods. Changes are based on original data and estimated by a statistical model.

Year	Control period (cells/ml)	effect period (cells/ml)	change	estimated change
1995	140.000	154.000	10%	8%
1996	133.000	140.000	5%	3%
1997	120.000	152.000	27%	15%

Estimated changes in SCC for the different categories of daily milk production are presented in table 2. Cows with the highest daily milk production in the control period (>35 kg/day), have the largest increase in SCC (21%).

The estimated changes in SCC for the different parity groups were –10%, 10% and 28% for the parities 1, 2-3 and parity ≥ 4 respectively. These estimations all differed significantly and show that the older cows have the greatest increase in SCC in the effect periods.

Table 2. Estimated change in SCC for the different categories of daily milk production in the control periods.

daily milk production (kg/day)	<15	15 - 20	20 - 25	25 - 30	30 - 35	>35
Estimated change in SCC	4% ^{a}	0% ^{a}	12% ^{ab}	4% ^{a}	13% ^{ab}	21% ^{b}

^{a,b} Means with different superscripts differ significantly at $P<0.05$

Table 3 presents the mean daily milk yield in the effect and control periods and changes in daily milk yield per year. Milk production was most decreased in 1997 compared to 1995 and 1996. The difference between 1995 and 1997 is remarkable since both years had comparable warm summers. The only difference is the fact that the effect period was in 1997 one month later than in 1995 and 1996.

Table 3. Mean daily milk production in the control and effect periods. Changes are based on original data and estimated by a statistical model.

Year	control period (kg/day)	effect period (kg/day)	change	estimated change
1995	24.7	23.7	- 4.0%	- 3.3% ^{a}
1996	25.8	24.4	- 5.4%	- 5.6% ^{a}
1997	24.9	21.8	- 12.5%	- 12.2% ^{b}

^{a,b} Means with different superscripts differ significantly at $P<0.05$

Estimated changes in milk production by a statistical model for varying milk production indexes are presented in table 4. Milk production decrease is greatest for the high producing cows in a herd.

Table 4. Estimated change in daily milk production for the different categories milk production indexes in the control periods.

daily milk production (kg/day)	<70	70 - 90	90 - 110	110 - 130	>130
estimated change in milk prod.	- 4.0% [a]	- 4.1% [a]	- 5.6% [a]	- 8.5% [b]	- 12.8% [c]

[a,b,c] Means with different superscripts differ significantly at $P<0.05$

There was no apparent trend in effect of parity on milk production decrease. Only parity 1 and 2-3 differed slightly in milk yield decline.

Discussion and conclusions

As a first step in the Dutch research into heat stress, the anecdotal evidence of the relation between high temperatures and an increased BMSCC has been verified statistically (study 1). This means that the assumption that heat stress occurs in the Netherlands during hot periods seems to be true. Unfortunately humidity, an important factor in the occurrence of heat stress, could not be taken into the research. In the Netherlands, not many farmers have taken measures against heat stress. However, measures such as keeping the cows inside during hot periods, do seem to be effective. A study was carried out in which farmers with and without an increase in BMSCC during a hot period were asked to fill in a questionnaire. The results showed that farmers without an increase in BMSCC during a hot period adjusted the grazing routine more often than farmers with an increase of BMSCC. The most effective measure was to keep the cows inside during daytime (Poelarends et al., 1999).

In a next step (study 2), heat stress was analysed at the cow level. The data in that study show that during summer, milk production declined and SCC increased. The increase in SCC seemed to be highest during warm summers ($P=0.06$). Both summers, 1995 and 1997 were warm, but milk yield decline was significantly larger in 1997 than in 1995. A possible reason for this may be the fact that in 1997 the effect period was one month later than in 1995. Pasture quality might also have had an effect on the difference in milk production. High producing cows were the most susceptible to an increase in SCC. Based upon literature, some theories can be made about the physiological background of heat stress under mild climatic circumstances (Poelarends et al., 2000).

It can be concluded that heat stress in mild climatic circumstances does occur. Moreover, the dairy cow characteristic parity and milk production are also important factors in the cow's reaction to mild heat stress. In order to gain more insight in the occurrence, effects and prevention of heat stress in mild climatic circumstances, further research should focus on the state of infection of the cows and the relationship with changes in SCC under mild heat stress. Further research should also focus on the role of certain hormones and metabolites in the responses of dairy cows to mild heat stress. Besides on physiological parameters, further research should also be directed towards cost-efficient methods to reduce heat stress in these circumstances.

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