

# Heat Stress in Dairy Cattle: Major Effects and Practical Management Measures for Prevention and Control

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## Abstract

Over the past years we have experienced several periods of heat waves, sometimes of short, other times of longer duration. This phenomenon will, most probably, be more frequent in the years to come. Heat waves may have detrimental effects on cattle production, health, welfare and reproduction. The question is whether cattle farmers and even veterinarians are sufficiently prepared and instructed to counteract or, even better, prevent the negative effects of heat stress in their cattle. This paper reviews the most relevant issues associated with the occurrence of heat stress, and provides practical measures to counteract and prevent the negative effects of heat stress in cattle.

## Introduction

Over the last few years we have experienced several weeks of high ambient temperatures during the spring and summer seasons in Western Europe and the USA. Temperatures over 30°C or 40°C during a certain number of days may be detrimental for optimal physiological functioning of the organism, and even death may occur. Details on physiology and pathophysiology are given in a subsequent section. The high temperatures can have negative consequences for milk production, and for reproduction, welfare and health, in dairy cattle, but also beef cattle may be affected. Especially high yielding dairy cattle would be susceptible because their thermo-neutral zone is rather limited as compared to low yielding cows [1]. However, it is not clearly established how the physiological response of cattle to heat stress occurs and what exactly these negative effects comprise. Moreover, the measures for prevention or controlling those effects are often still issue of debate.

The objectives of this review paper for practice is to provide the general background on heat stress occurrence addressing the most relevant issues, and to present, as a practical review, measures for prevention and control of some major negative effects related to heat stress.

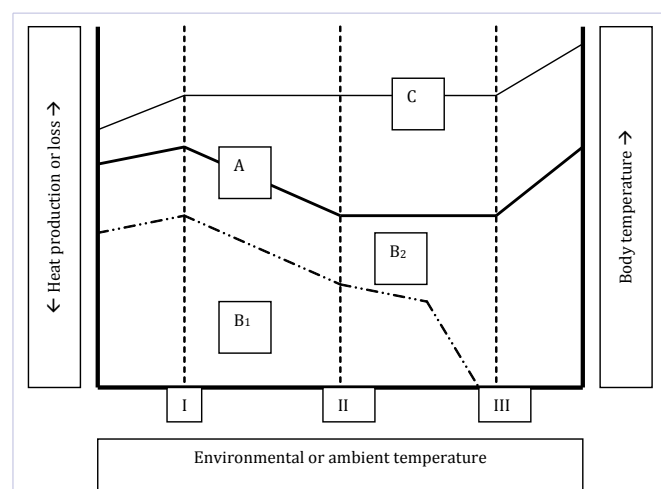
## Thermo-regulation and heat stress in dairy cattle

From a biological point of view, there is evaporative and non-evaporative heat loss; there are three non-evaporative

ways by which animals can get rid of their thermal body load: conduction, convection, radiation (Figure 1). In the zone I-III the animal can maintain a constant body temperature; in zone I-II and zone II-III heat production and heat loss is regulated. In zone I-II, heat production increases in order to maintain homeostasis. Zone II-III is the thermo-neutral zone, where heat loss is kept constant. Factors other than climate (e.g. ration, milk yield level, activity) determine the heat production in that zone [2]. The temperature points II and III are the lower and upper critical temperatures respectively, beyond which cold stress and heat stress respectively occur.

When temperature increases beyond a given critical limit, the non-evaporative ways of heat loss appear to be far less efficient. And if temperature rises even more, the cow changes from a non-evaporative to an evaporative way. However, the latter is strongly dependant on the level of air humidity.

The thermo-neutral zone of dairy cows in full lactation is, roughly speaking, between -5°C and +20°C for adult dairy cows



**Figure 1:** The general concept of thermoregulation: the relationship between heat production (A), heat loss ( $B_1$  = non-evaporative;  $B_2$  = evaporative), body temperature (C) and ambient temperature (after L.E. Mount, 1974, in Schrama et al. ) [2].

and between 10°C and 25°C for younger cattle [3,4] and the upper critical air temperature is around 26°C [4,5]. Differences between breeds and between individual cows exist. The thermo-comfort zone for dairy cows would be between 10°C and 25°C [4]. It has been stated that beef cattle experience problems when the temperature is above 32°C, especially at low wind speed (8-16 km/hr) and/or higher Relative Humidity (RH) levels.

A heat stress period can be defined as days on which minimal air temperature is around 20°C and maximum air temperature is at least 31°C, together with an air humidity level higher than 60%. Commonly this period is at least 17 hours [6].

**Factors affecting the susceptibility of cattle for heat stress**

There are different factors, not related to climate, affecting the susceptibility of cows for heat stress; they are listed in Table 1.

High yielding Holstein-Friesian cows in first, second or third parity at the first stage of lactation are the most susceptible: their heat production is twice that of low yielding or dry cows. The respiration rate of heat stressed cows increases from e.g. 20/min in normal conditions to 100/min or more in heat stress conditions. Once ambient temperature passes over 25°C one may already observe an increase to 50/min. It could be argued that heifers-due to their relatively larger body surface and lower level of metabolism- generate less heat than adult cows. Studies by West [7] have shown that heifers at 600 kg body weight produce more heat than heifers of lesser body weight, and hence are more prone to heat stress.

The severity of heat stress effects depends on the duration of exposition and severity of the heat stress imposed. For example, a heat stress condition on one single day may have no effect at all because the cow still can adapt, while heat stress during days or weeks can have considerable negative effects, which will be aggravated by higher air humidity levels.

**Formulas to assess heat stress**

We can use a formula for assessing heat stress, in which both temperature and air humidity are included [8,9]: The Temperature-Humidity Index (THI). Heat stress which usually

**Table 1:** Some major factors affecting the dairy cow’s susceptibility to heat stress [1].

|  |  |
|--|--|
| Breed (imported Holstein-Friesian versus local indigenous breed) | Body condition score (high versus low)             |
| Parity (younger versus older)                                    | Behavior (active/aggressive versus quiet)          |
| Level of milk production (high versus low)                       | Housing conditions (well versus poorly ventilated) |
| Lactation stage (early versus late or dry)                       | Pasturing conditions (shady versus non-shady)      |
| Level of feed intake (high versus low)                           | Quality of feedstuffs in the ration                |
| Ration composition (protein rich versus poor)                    |  |

is accompanied by a rise in air humidity is expressed with this formula. Humidity is a relevant parameter in this formula because at high humidity levels a cow can no longer or insufficiently get rid of the body heat load through (evaporative) sweat and respiration, and hence is far less successful in reducing her deep body temperature. We speak of heat stress with notable effects when THI is over 64 (minimal heat stress), over 72 (moderate heat stress) and over 76 or 77 (maximal heat stress) According to the following: “At THI of 84 or more, death occurs [7,10,11,12]. The THI can be used to assess heat stress occurrence in the field; it is calculated as follows [13]:

$$THI = 0.8 T_a + RH (T_a - 14.4) + 46.4$$

In which  $T_a$  = ambient air temperature (°C) and RH = relative air humidity (%)

For example, at a temperature of 32°C and a RH of 86%, the THI will be 87; if only RH drops to 45%, the THI becomes 79.9. An even more simple formula is the Heat Index (°F) = 1.9 x Temp (°F) x RH + 10.

An alternative formula was given by Morton et al. [14] using dew-point temperature and ambient temperature as follows:

$$THI = T_a + 0.36 \times \text{dew-point temperature} + 41.2$$

In which  $T_a$  is the ambient air temperature, and

$$\text{Dew-point temperature} = 237.3 \times \ln (RH/100) (17.27 \times T_a) + 237.3$$

This formula is more complicated and, from a practical point of view, less attractive than the first formula given.

A third formula was presented by Kadzere et al. [1], which require information of wet (WBT) and dry bulb temperatures (DBT) as follows:

$$THI = 0.72 (WBT-DBT) + 0.46$$

This formula is not very attractive neither from a practical point of view. For more and other formula, we refer to the internet (www.britannica.com; www.publish.csiro.au; www.srh.noaa.gov/jetstream/ or http://en.wikipedia.org/wiki/Heat\_index for example).

**Negative effects of heat stress on dairy cattle**

The first signs of thermal stress are a drop in feed intake (0.85 kg DM less for each rise in °C ambient temperature), a drop in energy balance, and often a loss in nitrogen balance (due to less feed intake), a drop in milk production, and a loss of activity.

With regard to milk production it has been reported that losses up to 600 or 900 kg milk per cow per lactation occur [7]. At a temperature of 29°C and a RH of 40% one would lose between 2 and 7% of milk; if RH rises to 90%, one would lose between 17 and 31 % milk yield per cow affected [15]. Each 0.55°C increase in ambient temperature may be accompanied by a loss of 1.8 kg milk and a 1.4 kg DM loss of daily feed intake. Each unit increase in THI over 72 would cause a loss in milk yield of 0.2 to 0.9 kg of milk per affected cow.

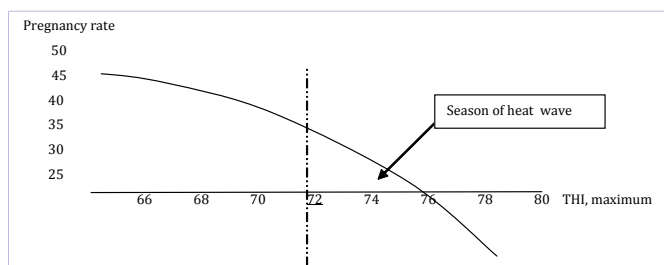
Metabolism is disturbed: about 30% of the energy

consumption is for maintenance of thermo-neutrality, while during days of high ambient temperatures (about 10 to 30 %) more energy is required for this physiological process. Together with lowered feed intake this is the reason for a drop in milk yield. Moreover, blood circulation is re-orientated towards peripheral tissues for cooling purposes.

Other metabolic changes have been reported: an increase in serum prolactin which affects follicle development negatively; a drop in plasma vitamin C, an anti-oxidant which contributes in protection of the young embryo [16,17] decrease of triiodothyronine and thyroxine [3]; respiratory alkalosis; urine excretion of bicarbonate; base-excess reduction; loss of serum potassium; hyperventilation [7].

Ration composition can contribute to heat stress effects: a crude protein content of 18 or 20% instead of 14 or 16% may aggravate the situation; lysine rich rations (fish meal, blood meal, and soya) at for example 1% of DM or 241 g crude protein/day may counteract these effects [6]. The level of rumen degradable protein should remain below 61% of total crude protein content, and should not pass the recommended level with more than 100 g total nitrogen/day. Fat supplements in the ration should not exceed 6 or 7% of DM in order to avoid rumen fiber digestion problems under heat stress conditions. More research is needed to effectively determine which nutrients and products are truly adequate to alleviate the metabolic effects of (severe) heat stress in dairy cattle.

Mortality may occur at THI levels over 84 during several hours without the cattle having the opportunity to counteract or adapt during the night when THI remains around the 74 [18]. Immunity may be reduced due to heat stress effects on hormone balances (steroids, GnRH, prolactin), to severe negative energy balance and to oxidative stress at start of lactation [13]. Immunity in calves, expressed in serum IgG levels, may be suppressed during heat stress periods, but this could also be related to poor vitality of the calf at and after birth at a dam under heat stress, a refusal to uptake colostrum without interference of colostrums quality [7]. Colostrum quality should at all time are under surveillance before and during periods of heat stress: check of colostrum quality after milking by colostrometer and check of serum IgG in calves by refracto-meter or laboratory. At the same time, it should be realized that calves in outside igloos are more affected



**Figure 2:** The relation between pregnancy rate the average monthly THI per day [14]. Note that the threshold is at THI 72, above this value there is more or less severe heat stress.

This article is based on a short paper presented at the European Buiatrics Forum, Marseille, France, and June 2011.

**Table 2:** Some major prevention and control measures in situations of heat stress in dairy cattle. The ‘a’ refers to the text where the respective issues are elaborated in more detail.

| Farming area                         | Control and Prevention Measures  |
|--------------------------------------|--|
| Nutrition                            | Increase the frequency of feeding to 4-6 times a day; give the highest proportion at late evening or during the night  |
|                                      | Reduce the effects of a negative energy balance around calving: maintain feed intake at a normal level during close-up and fresh cow period. Take care of optimal claw health.   |
| Drinking water                       | Increase the number of drinking places. Total width of drinking places must be 600 to 900 cm for 100 cows. Provide water of low temperature (< 15°C) and clean troughs every 2 days. Check water quality beforehand (chlorates, sulfates, microbes) regularly.   |
| Barn climate                         | Create shadow over feed bunks (at 4-5 m <sup>2</sup> per cow) at 4 m height  |
|                                      | Install and use appropriate fans <sup>a</sup>  |
|                                      | Install and use showers, water spray producing devices, or sprinklers <sup>a</sup>   |
|                                      | Increase the number of sprinkling and drying cycles per day <sup>a</sup>   |
| Management of reproduction and other | Do not use a natural service bull (spermatogenesis will most probably be disturbed)  |
|                                      | Provide cooling to dry cows from 4 weeks before calving onwards (sprinkling, drying, shadow, fanning)  |
|                                      | Create shadow in the pasture, and make sure that wind can pass freely over the pasture plots (no trees or bushes)  |
|                                      | Reduce the walking distance from pasture (or pen) to milking parlor and back, if possible  |
|                                      | Reduce the time the cows spend outside; reduce the waiting time before milking; reduce the number of cows per group for milking.   |
|                                      | Check more frequently the vitamins and mineral status of the feed (rations): K, Na, Cl, P. If needed, increase K, Na, Mg in the ration   |
|                                      | Adjust ration composition (≤ 2-3% fat in DM; protein level < 18%; rumen degradable protein < 61 % of total protein; salt; Lysine 1% of DM; water addition (4-5 liter per 20 kg DM). Eliminate citrus pulp from the ration because it contributes to increase heat production                                       |
| Calves                               | Check IgG in colostrum (colostrometer) and in serum of all calves born in heat stress periods (refractometer; laboratory)  |
| Other measures                       | Reduce cattle density in the barn (alternate groups inside and groups outside); reduce group size.   |
|                                      | Check behavioral preference of cows for cubicles and resting areas. If deviations occur, take measures (see text)  |
|                                      | Avoid cattle handling/processing/treatment because this increases body temperature with some degrees. If handling is needed, let the cow be confined for less than 30 min and do it at night or early morning (before 06.00 hrs). Handling areas should preferably be provided with a fan and sprinklers/sprayers. |
|                                      | Maintain a program for controlling (biting) flies  |

by heat stress than calves housed otherwise.

Indirect and direct effects of heat stress on reproductive performance have been reported. Among indirect effects are for example the effects of a severe or long-lasting negative energy balance and ketosis. Direct effects are, for example, disturbed follicular development, disturbed steroid levels, less estrous expression (less intense, shorter duration), more silent heats, endometrial dysfunction, reduced spermatogenesis, reduced pregnancy rates after AI, increased early embryonic mortality [7,12,13,16,19]. It has been reported that a THI > 72 on the day of IA and 6 days after IA lead to a reduction of pregnancy rates (Figure 2). An elevated THI the week before IA or 3 to 5 weeks before IA lead to a reduced pregnancy rate [14]. This seems to confirm a carry-over effect. Effects of heat stress may be detected during hot summer season until autumn. It is assumed that this is due to the fact that antral follicles need time to develop and once affected by heat stress there will be a delay in reproductive processes. Heat stress also would affect the rates of retained placenta and metritis, possibly due to the reduced immunity [1]. The effect of heat stress on health parameters seems primarily indirect: through negative energy balance, ketosis, and reduced immune responsiveness.

### **Practical management measures to prevent and control heat stress effects**

The most important control and prevention measures are listed in Table 2 (after 7,12,20)].

Feeding a meal 4 to 6 times per day is always better than twice daily. This higher frequency is meant to reduce the total metabolic heat production at each meal, especially in high yielding dairy cows. Moreover, feeding the highest proportion of the daily feed during the night may contribute to reduce the negative effects of heat stress. Supplying, each day, additional fresh water in the feed bunk (TMR: 4-5 liter per 20 kg DM) and/or in the water troughs avoids the rations from becoming too dry. If the ration sticks to the boots, diminish the water volume added in the ration. Access to the drinking places must be facilitated and enlarged; more drinking places should be installed and/or the total width of drinking place upgraded to a level of 600 to 900 cm for 100 cows, depending on barn lay-out. Water quality must be checked to find out whether the chlorate and sulfate contents are not too high, because these may affect milk yield negatively [20]. Moreover, checking the water for micro-organisms may help in keeping the water of high quality. It is advised to provide the cows with water of 15°C or less.

A negative energy balance at the start of lactation will aggravate the situation, and affect milk production, reproduction, welfare and health negatively. Hence, it is important to limit the severity and the duration of such negative energy balance by evaluating and adjusting the nutrition and stabilizing feed intake, and by a proper management of the dry cows from 4 weeks prior to expected calving onwards. Ration evaluation refers to, for example, total protein content (<18%), rumen degradable protein content (< 61% of total protein content),

lysine supplementation (at 1% of total DM), fat content ( $\leq$  2-3% of DM), proportion of grains in the ration, vitamins and minerals. Mineral balance must be evaluated at the end of the dry period and at the start of lactation. Absorption of phosphor in the portal circulation can be reduced by 50% during heat stress [20]. Fat supplementation needs to be revisited because their negative or positive effect depends on the kind of fat source (for example cotton seed in a ration of alfalfa). The role of fungi and yeast in the ration in relation to heat stress management needs to be established. In spite of studies (on *Aspergillus oryzae* and *Saccharomyces cerevisiae* contamination in the ration), indicating that rectal temperature and respiration rates decreased, while milk yield increased with 2.5 kg milk/cow/day mainly at the start of lactation, other studies showed contradictory results [6].

It is advised to provide shadow over the feed bunk space in order to avoid that the feed dries too much and too rapidly. The material for shadowing is equally important [21]: white aluminum, nylon with a two-sided layer of neoprene, galvanized white metal, non-painted wood and hay are all better isolated than standard aluminum, asbestos, 80-90% solid tissues, or wood slats (5 cm open, 5 cm closed).

If one decides to keep the cattle inside the barn, it is paramount that all other measures must be taken as well (more drinking spaces, more cooling cycles, higher feeding frequency). It is good to remember that a roof at 33% slope and openings high in the roof contribute more to limiting the increase of the respiration rate of cattle than all other options [21]. A height of at least 430 cm of the side walls improves greatly the natural ventilation in the barn. The orientation of the barn must be such that the direct sun radiation during the afternoon is least (sun radiation during the morning is less severe). The latter can be easily assessed by observing the preference behavior of cows in their occupation of cubicles and/or resting areas during the day. It should be considered to install curtains in the side walls to prevent the direct sun radiation from entering the barn between 1 and 8 pm, especially in later summer and September. Outside this time frame, the curtains must be opened to allow natural ventilation.

One of the most relevant issues are regarding the sprinkling and drying of the cows. There are, basically, two techniques: (1) fans; (2) low pressure sprinklers or ordinary sprayers. These sprinklers eject 1.25 liter water per m<sup>2</sup> per minute at each nozzle. The principle is to first sprinkle the cows and then to fan them, sprinkling being more important than drying because of the positive effects of the former on respiration rates. After 90 min of cooling the respiration rate may be reduced with 45%.

A typical cooling cycle comprises 1-2 min of spraying (sprinkler; shower) +5 min drying (by forced ventilation of 0.33 m<sup>3</sup> per cow). This cycle is repeated during 30 min. At least two 30 min series of cooling cycles should be applied per day: the first before noon, the second before the evening milking. If ambient temperature remains high during the night, one should not hesitate to add another 30 min cooling cycle series during the night. If, at night, ambient temperature remains above the 24°C,

then every 4 hours the forenamed 30-min cooling cycles must be applied [21].

Cooling cycles can be applied in the barn (or pen), behind feed bunk and feed rack, in exercise areas, in waiting areas, milking parlor and at exits to the pasture plots. They should not be applied above the feed bunk itself, not in resting areas, and not above cubicles. One should not hesitate to let the sprinklers and fans run for the total duration of the milking time. It is also possible to install a "shower alley" somewhere in the barn where it is most convenient for cows and man; it is sufficient to just spray the cows, but additional fanning will even improve the results.

Regular fans have a diameter of 76 to 91 cm and they jet 0.47 m<sup>3</sup> air per fan. One fan per 10 cows or per 13.5 m<sup>2</sup> surface is installed, parallel to cubicle rows, in the length direction of the barn, above the exercise area at a height of 250cm, at each 2m length. The angle is 30° on the vertical axis. Air speed should not exceed 12 to 19 km/hr (330Liters of air per min). Sprinklers have each a capacity of 18 liters of water per hour, at a pressure of 300 to 400 kPa; or 1.25 liter per m<sup>2</sup> per nozzle per min [22]. Sprayers will yield 36 L water/min at a pressure of around 275 kPa (2.76 Bar). Water tubes have a diameter of 1.3 cm or 1.9 cm, and should not have too many 90° angles, because each such angle will dramatically reduce the dynamic water pressure with 25% [23,24].

In general, fans should function starting at 22°C and above; sprinklers should start from 24°C and above, every 5 to 15 min (unless cooling cycles are applied; see previous section). In large barns (for example 4 cubicle rows or more) larger fans are installed: 91 to 120 cm diameter; with a capacity of 400 L of air per cow per min; placed every 9 or 12 m respectively. Alternatives are the large ceiling fans with a diameter of 7 m. In tropical countries one may install devices for cooling by vaporization: fans are placed in front of a kind of a spiral spring mattress fence along which water is streaming downward. This approach is, however, not possible in e.g. Europe because of the, too often, high level of humidity.

**Practical problems at the application of cooling cycles**

In the application of cooling cycles presented here, several problems may occur. For example, because the diameter of water tubes is too small; there are water tubes lacking there where they are needed most; there are too many 90° angles in the water tube system leading to loss of water pressure; the exits of sprinklers or sprayers are too small: droplets are too small; there is too much wind which disperses the water that is being sprinkled or misted; it appears to be difficult to recollect the water after each cooling cycle; fans appear to be poorly located; the air speed of fans is too high; electrical capacity of the on-farm power system appears to be a limiting factor; or fans are poorly maintained. When the cows enter the milking parlor with wet udders, then you know that cows have been over-showered (too many cooling cycles; too long duration of cycles). Moreover, the risk for contamination and intra-mammary infection increases this way, especially when udders are not properly dried at pre-milking preparation.

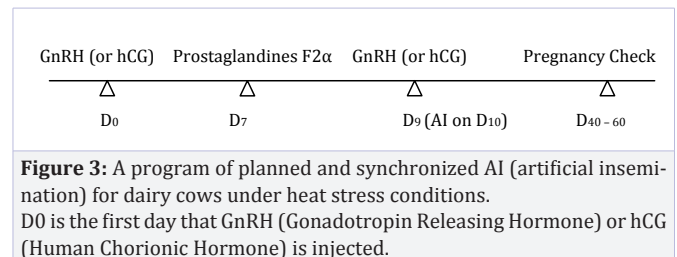
This will also affect the quality of cubicles, resting areas and bedding material which will get wet too; this again will increase risks of intra-mammary infection (coli form bacteria). The advice of technical specialists should be obtained when planning and installing cooling devices.

**Discussion and Conclusions**

There is a wide variation between the different breeds regarding their resistance against heat stress. Moreover, the husbandry conditions differ greatly between countries and regions, as well as between farmers. The genetic selection for high milk yield has been accompanied by a loss of capacity to maintain homeostasis under all conditions. If it would be possible to select genetically heat stress resistant cows, then milk yield capacity would be lost to a certain extent: traits are negatively correlated. The same is applicable to traits such as sweat, hair coat color, tissue conductance [7]. These are just a few reasons why it is not feasible to provide the one and only receipt for controlling heat stress. We have to adapt solutions to each individual farm and husbandry situation.

One should bear in mind that the THI was established years ago. Since then, average milk production per cow has increased. Especially high yielding cows are very susceptible to heat stress; their critical THI is rather around the value of 68 than at 72 or higher. The negative effects of heat stress on reproduction do not have a mono-factorial cause. They are rather the result of an accumulation of effects provoked by many determinants [16]. It is without doubt due to this phenomenon that hormone injections to improve reproductive performance in heat stressed cows do not work out. Applications of GnRH to improve reproductive performance in these cows were poorly successful, and hCG injections showed no result at all, just like intra-vaginal CIDR devices with progesterone [16,19]. A program of planned and synchronized AI could be another approach, but will not guarantee success and is rather expensive [16,19] The principle of such a program is illustrated in Figure 3.

Most of the authors, who address heat stress in dairy cattle, advise to evaluate and adjust the rations. Unfortunately it is impossible to provide the one sole solution because it will depend on region, husbandry conditions, feedstuff available, feed quality and management quality what could be feasible. Some tips and tricks have been given here, but the advice of a nutritionist should be highly valued. For example, a high content of protein in the ration will require much energy for metabolising; this energy may be lacking due to an existing negative energy balance. Much additional heat will be produced which aggravates the heat stress



situation for the cow. So, protein content in the ration must be limited: below the 18%. Moreover, in the example of too high protein content there is the risk of creating high urea levels that will represent an additional burden for the liver. Supplementing the ration with fats has been proposed here, but again, it will depend on the type of fat (source) and the composition of the ration to determine what is possible [7]. Rations rich in fiber will increase heat production, while the consumption and conversion of metabolizable energy will decrease. At all time, one has to check regularly the cows for the development of rumen acidosis, even more so when rations are rich in grains. Supplementation of Na or K, and vitamins like A, E and C have not always yielded positive results. Reports have appeared that state to increase the Cation-Anion Balance from 12 to 46 mEq, or from 25 to 50 mEq (Na + K-Cl)/100 g DM in order to increase/stabilize feed consumption and milk yield, but results have to be substantiated; there are too many contradictory results [7].

The investment costs for sprinklers/sprayers and fans represent a high value, which for several farmers will be a reason not to go along. On the other hand, one should realize that this investment is done for 10 years. Moreover, the losses due to milk yield decrease, poor reproductive performance, as well as health and welfare problems may represent a much higher cost than the cooling investment cost. To disperse costs it is always possible to invest in stages: (1) adapt the width of drinking places to 600-900 cm per 100 cows; make sure that the water is of good quality and fresh; (2) install sprinklers/sprayers and fans in the waiting area; (3) install sprinklers/sprayers and fans among the dry cows; reduce the number of cows per group; (4) install sprinklers/sprayers and fans behind the feed rack (Table

3) [25]. Remember that – instead of sprinklers and professional tubes – one may buy rather cheap facilities for watering plants at local gardening enterprises. Some elementary criteria should, however, be met: air speed of fans ≤ 3m/sec; large droplets at sprinklers. Mist producing devices (‘fogging’) are highly sensitive to wind, are not truly soaking the cows and, therefore, are not advised.

Heat stress problem in cattle can cause problem in humans. For example, at 32°C about 30% of the work output is lost, while accuracy drops with 300%; these figures become more dramatic when temperature further rises. General signs in humans are: exhaustion, mood changes, emotional responses, confusion, headache, heat stroke. General measures to be taken are e.g.: give employees more rest (15 min per hour), increase frequency of water intake, provide shade in working areas, and give people less strenuous work or change their working hours from day to night-time [23].

A paramount issue is that one should not wait till the last moment to take prevention or control measures. When it appears obvious that a heat period is about to arrive, it is highly indicated to take the necessary measures immediately. From an economic point of view it is also indicated to invest in sprinklers/sprayers and fans, especially when the farmers know that the frequency of such heat periods will increase about each year. Finally, the elements named in Table 2 should be considered as elements of a general farm protocol, a Good Heat Stress Control code of practice. The veterinary practitioner is well positioned to advise the dairy farmer in the different domains named in Table 2, and hence can play a substantial role in limiting the negative effects

**Table 3:** Examples of installing spraying devices/sprinklers and fans in the barn.

| Location of the devices  | Type of device                        | Explication details   |
|--|---------------------------------------|---|
| <b>Barn</b>  | Fans                                  | Behind the feed rack, not above cubicles or resting areas, not above feed bunk. Install fans in a line parallel to cubicle rows   |
|  |                                       | Diameter 76 to 91cm. Capacity 0.47m <sup>3</sup> . One fan for each 10 cows, or for each surface of 13.5 m <sup>2</sup> , or for each 2m length of the barn. Height should be at 250cm. Install at an angle of 30°C on the vertical axis.   |
|  |                                       | Air speed should not exceed 375 to 425 L/min, or about 12 to 20 km/hr (5 m/sec)   |
|  |                                       | Alternative option = large fans of 7 diameter, for each 20m barn length, at an angle of 30°C and each covering 400 m <sup>2</sup> barn surface.   |
|  | Sprinklers                            | 1.25L water per min, at low pressure: 300 kPa (<3 bar)  |
|  | Sprayers                              | At a height of 150cm above the cows, at every 2m length of the barn. Capacity of 300 L/hr.  |
| <b>Waiting area</b>  | Fans                                  | 1 fan of 91cm diameter for each 40 m <sup>2</sup> of surface  |
|  | Sprinklers                            | 18L of water per hour at a pressure of 300-400 k Pa. Water tube diameter 1.3 or 1.9 cm.   |
|  | Sprayers                              | At 150 cm above the cows, at each 2 m length of the barn. Capacity 300L of water per hour.  |
| <b>Milking parlor</b>  | Ventilators<br>Sprinklers<br>Sprayers | Specifications as named under “barn” above or for a 2x14 herringbone 9 fans: 3 above the pit, and 3 above each side. For a 2x6 herringbone: 1 above the pit and one above each side. A mist producing device may be added to the ventilators but has great disadvantages (susceptible for wind!). |
| <b>Shower room in barn</b>                                       | Fans, Sprinklers,<br>Sprayers         | Located somewhere in the barn where it is most convenient for cows and man. One sprayer for each 2m, and 2 ranges of fans. Do not forget a rubber topping on the floor.   |
| <b>Cow handling area</b>   |                                       | If needed; 1 fan + 1 spray nozzle for 5 cows; water tubes 1.3 or 1.9cm diameter   |
| <b>Entrances to the barn, exits to the pasture plots or pens</b> | Fans, Sprinklers,<br>Sprayers         | See specifications as named above under “Barn”  |

of heat stress in dairy cattle and the associated economic losses. As such a dairy farm consultant, he will have high added value for the farmer.

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