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The role of slow release non protein nitrogen (NPN) during heat stress

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As summer is starting and temperatures are rising across all Europe, most people start thinking about where they will spend their summer holiday. However, there is a specific category of EU people whose thoughts are concentrated on a different topic. Dairy farmers are now facing one of the most critical periods of the year. During summer, dairy cows are not able to cope properly with the increase of temperatures and humidity, experiencing the phenomenon known as heat stress (HS).

Heat stress is defined as the point at which a dairy cow cannot dissipate enough heat to maintain a normal body temperature. Although the effects of heat stress are more severe in hot climates such as in southern EU, dairy cows in Northern EU could be affected by heat stress as well, mainly due to the high humidity index.

By definition a cow is in her thermoneutral zone when the combination of temperature and humidity (temperature humidity index – THI) is in the range of environmental temperatures where normal body temperature is maintained and heat production is at the basal level. When environmental conditions move out from the thermoneutral zone, dairy cattle begin to experience either heat stress or cold stress (Figure 1).

Figure 1: Temperature Humidity Index (THI)

Temperature Humidity Index (THI)

	Relative Humidity %								
C	20	30	40	50	60	70	80	90	100
22	66	66	67	68	69	69	70	71	72
24	68	69	70	70	71	72	73	74	75
26	70	71	72	73	74	75	77	78	79
28	72	73	74	76	77	78	80	81	82
30	74	75	77	78	80	81	83	84	86
32	76	77	79	81	83	84	86	88	90
34	78	80	82	84	85	87	89	91	93
36	80	82	84	86	88	90	93	95	97
38	82	84	86	89	91	93	96	98	100
40	84	86	89	91	94	96	99	101	104

No heat stress
Moderate heat stress
Severe heat stress
Dead cows

When a THI of 68 is reached, high yielding cows show moderate heat stress (Bernabucci et al., 2010). This level is breached and cows can start being stressed at temperatures as low as 22 °C and high relative humidity (90%).

Heat stress is thus directly linked to temperature and humidity. However, other factors such as length of heat stress period, degree of cooling during the night, ventilation and air flow, water availability and factors linked to the specific animal can increase or decrease the severity of heat stress.

How do cows respond to heat stress?

- Increased body temperature: Rectal temperature can be used to measure the adversity of thermal environment. A rise of 1 ºC or less is enough to reduce performance in most livestock species (McDowell et al., 1976).
- Increased respiration rate: Respiration rate and panting are a good indicator of HS. If respiratory rates are greater than 80 breaths per minute on at least seven of ten cows, they are also probably showing signs of significant heat stress. If more than five cows out of ten have respiratory rates greater than 100 breaths per minute, then immediate action should be taken to reduce heat stress (Fidler P.A., VanDevender K.)
- Behavior: Cows suffering from HS are usually lethargic and drastically decrease their activity. Typical signs of HS are cows crowding under shade, at water tanks and looking for cool areas in the barn.
- Decreased feed intake: Unabated HS can decrease feed intake up to 35%. Even on well-managed and well-cooled dairies, heat stress can decrease feed intake by 10-15% (Collier and Beede, 1985; Armstrong, 1994; West, 2003).
- Increased water intake: HS increases water consumption by at least double the normal level in temperate zones. Water and macro-mineral needs, heavily influenced by demands to maintain homeostasis and homeothermy, are altered for lactating dairy cows during heat stress (Shalit et al., 1991).
- Metabolic changes: The mechanism by which HS impacts the productive and reproductive performances of dairy cows is only partially explained by a reduction in feed intake. It also includes an alteration of the endocrine status, a reduction in rumination and nutrient absorption and an increase of energy required for maintenance (Collier and Beede, 1985; Collier et al., 2005). These factors will determine an imbalance between energy uptake and energy utilization, explaining why cows lose significant amounts of body weight when subjected to HS.
- Decreased daily milk production: HS reduces milk yield, and the reduction in nutrient intake is generally recognized as the major cause of reduced milk synthesis. However, Baumgard et al. (2006) highlighted that the reduction of DMI can only account for 40-50% of the decrease in production when cows are under HS conditions, while 50-60% can be explained by other HS induced changes. On top of this, it is typical to have a reduction in milk fat and protein percentages, decreasing the value of the milk itself. These drops are usually common in all EU countries (Figures 2 and 3).

Figure 2

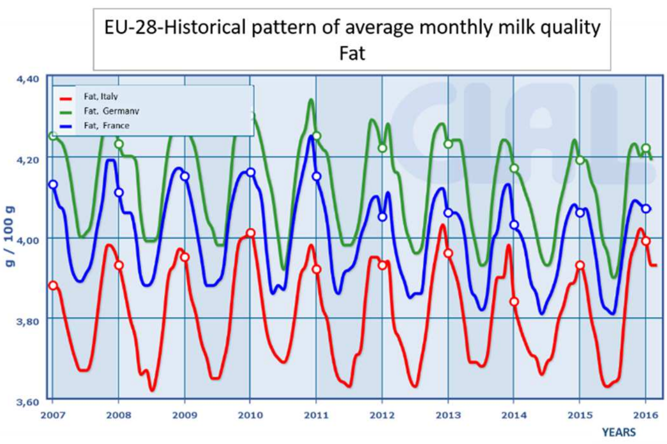
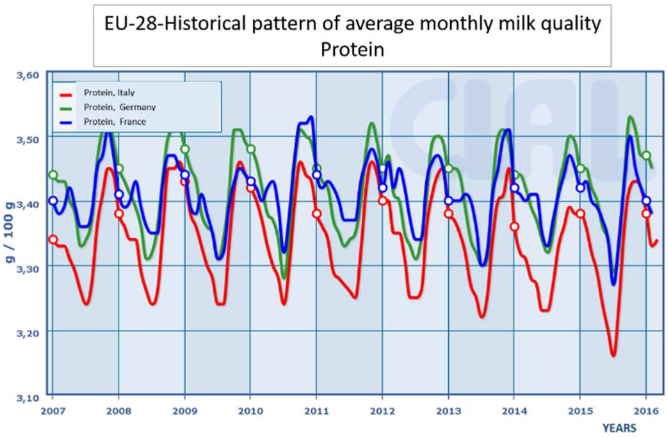


Figure 3



Effect of Heat stress on Rumen health

It is well known how heat stress can adversely impact rumen health. One of the ways dairy cows dissipate heat is through panting, increasing respiration rate, resulting in higher CO_2 (carbon dioxide) being exhaled.

In order to maintain a correct blood pH, the body has to maintain a ratio between HCO_3^- (bicarbonate) and CO_2 of about 20:1 (Baumgard et al., 2006). To maintain this balance due to the higher exhalation of CO_2, the cow starts to excrete more bicarbonate via urine instead of recycling it via saliva. Bicarbonate is the main rumen buffer endogenously produced by cows. Cows consuming 20 kg of dry matter can produce the equivalent of 3418 to 3617 g/d sodium bicarbonate in their saliva, depending on the level of forage in the diet (Erdman, 1988).

This reduction of bicarbonate concentration in saliva combined with increased drooling due to open mouthed breathing and overall reduced rumination during HS, makes the heat stressed cow much more susceptible to sub clinical acidosis (SARA).

Nutritional strategies to combat heat stress: the role of slow release NPN

Due to the reduced feed intake caused by HS and heat generally associated with forage digestion in the rumen, nutritionists typically increase energy density in the ration by increasing concentrates and reducing forages. Considering what is mentioned above, this strategy could lead to a further decrease in rumen pH, leading to a higher risk of SARA.

On top of this, cows tend to sort the TMR more during HS and to consume more feed at night when they get a little relief from the heat. Unfortunately, this not only compounds the problem with regard to SARA but can also lead to a more imbalanced synchronization of carbohydrate and protein digestion rates.

The use of slow release non protein nitrogen (NPN) allows you to reduce the inclusion of concentrates in the diet, increasing the percentage of forage in the diet without sacrificing nutrient density. This strategy will lead to a higher forage:concentrate ratio which will help maintain more optimal rumen function.

Table 1 shows two options for reformulating a diet during heat stress. The decrease in DMI usually leads to reformulation of diets with lower forage:concentrate ratios.

The inclusion of a slow release source of NPN such as NitroShure™ (Balchem Corporation, USA) may help keep a more rumen-friendly ratio between forage and concentrates, leading to higher predicted rumen pH, and less time spent under pH 5,6-5,8.

Table 1: example of diet reformulation for heat-stressed dairy cows.

	Concentrated Diet	*NitroShure™ Diet*
Corn silage 32.4329 med. *	24,00	24,00
Corn grain 64% fine	5,00	5,00
Alfalfa hay 53.16	2,20	2,40
Ryegrass hay 59.08	1,80	2,30
Soybean meal solv. 47%	3,20	2,40
Canola meal solv. extr. 34%	1,00	1,00
Hydrogenated fat	0,25	0,25
Min+Vit Dry Cow	0,50	0,50
Barley grain ground 51%	0,80	0,80
Sugarcane molasses 57%	0,70	0,70
Nitroshure NDS 15	0,00	0,12
Analysis		
DMI actual (Kg/d)	21,29	21,33
Total CP in ration (% DM)	16,11	16,06
Soluble Protein (% CP)	28,73	32,87
NDF (% DM)	31.13	32.36
Starch (% DM)	28.45	28.13
Forage:Concentrate	53:47	56:44
Ruminal parameters		
Predicted Ruminal pH (NDS)	5,99	6,03
Minimum ruminal pH	5,42	5,46
Maximum ruminal pH	6,57	6,60
Time below pH 5.6 (h/day)	3,78	3,13
Time below pH 5.8 (h/day)	6,31	5,50
Microbial production		
Total microbial prod. (g/d)	3383,65	3407,85
Total cost €/head	5,33	5,29

On the other hand, due to its unique release pattern of ammonia in the rumen, dietary inclusion of NitroShure™ will help in maintaining the ammonia level above 7-10 mg/dl of rumen liquor throughout the day. When below this threshold, microbial protein production is decreased due to a lower efficiency of the bugs in the rumen. This is particularly exacerbated during HS due to the feeding behaviour explained above. The result of a better synchronization of ammonia release and carbohydrate fermentation in the rumen can lead to a higher production of microbial protein and a higher passage of highly valuable amino acids at the gut level.

Moreover, replacing soybean meal with NitroShure™ in dairy diets resulted (as shown in table 2) in increased digestibility of organic matter, NDF and total carbohydrates (NDF + NSC). This will ensure both a higher energy availability for the animal, increasing the feed conversion rate and contrasting the typical negative energy balance linked to HS, and a higher production of acetate in the rumen leading to less milk fat depression in the hot season.

Table 2: *In vitro* digestion coefficient for dry matter, NDF and total carbohydrates when soybean meal is partially replaced with NitroShure^{TM} (Balchem Technical Research Report 2004:6)

Item	Control	NitroShure^{TM}	Difference in %
DM dig.	60	65.6	9.3%
NDF dig.	53.7	59.4	10.6%
Total Carbohydrates	46.6	50.7	8.81%

Conclusion

Provided that the first line of defense to manage HS is to cool cows as much as possible through an appropriate use of shades, sprinkling water and fans, there are many different complementary nutritional strategies available to help dairy farmers reduce the detrimental effects of HS in cows. The strategic use of a slow, controlled-release source of NPN such as NitroShure^{TM} can complement these strategies by helping to:

- Develop a more rumen friendly diet
- Increase rumen functionality and feed digestion
  - More microbial protein production
  - More energy available for the animal
- Balance the synchronization between protein and carbohydrates
- Increase milk components

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