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Abstract. The effect of a heat stress episode was studied in eight dairy goats bred under temperate climate with *ad libitum* access to water. The increase in temperature from 19 to 28°C (recorded at 5 pm) modified neither feed intake nor the global shapes of feed and water intake patterns. However, there was a 40% increase in water intake and the latency from the beginning of the afternoon meal to the first water intake decreased from 35 to 26 min. Blood PCO_2 decreased because the animals hyperventilated to reduce their body temperature, whereas rectal temperature increased by around 0.6°C. Milk production was not modified, but milk fat content decreased. A significant goat effect was observed for almost all the results. Goats from the Alpine breed drunk more water when expressed on a dry matter intake basis than those from the Saanen breed. This could be explained either by their higher level of feed intake which enhanced the post-prandial heat production or by the difference in latent heat dissipated through sweating linked to coat colour.

Keywords. Heat stress – Intake behavior – Lactating goats – Temperate climate – Water intake.

Effet d'un stress de chaleur sur l'ingestion d'aliment et d'eau chez des chèvres laitières élevées en conditions tempérées

Résumé. *L'effet d'un stress de chaleur a été étudié chez huit chèvres laitières élevées en climat tempéré et disposant d'eau à volonté. L'augmentation de la température de 19 à 28℃ (mesurée à 17 h) n'a modifié ni la quantité de ration ingérée, ni l'allure globale de la cinétique d'ingestion des aliments et d'eau. Par contre, la quantité d'eau bue a été accrue de 40 % et le temps de latence entre le début du repas et la première buvée, réduit de 35 à 26 min. La teneur en CO_2 du sang a diminué, car les animaux ont hyperventilé pour réduire leur température corporelle, alors que leur température rectale a augmenté de 0,6℃. La production laitière n'a pas été modifiée, mais le taux butyreux du lait a diminué. Un effet chèvre significatif a été observé sur la majorité des paramètres étudiés. En moyenne, les chèvres de race Alpine ont bu plus d'eau par rapport à la quantité de matière sèche ingérée que les chèvres de race Saanen. Ceci pourrait être dû à leur niveau d'ingestion plus élevé qui accroîtrait le dégagement de chaleur post-prandial, ou à une différence de chaleur latente dégagée par sudation liée à la couleur de leur pelage.*

Mots-clés. Stress de chaleur – Comportement d'ingestion – Chèvres en lactation – Climat tempéré – Ingestion d'eau.

I – Introduction

In recent years, temperate European regions suffered from unusually hot periods, as for example during the summer of 2003. The aim of this work was to study the effect of a hot period on feed and water intake of high-producing dairy goats bred in the Paris area, because most previous studies concerned ruminants under hot climates in areas where water is scarce. Moreover, drinking behavior is seldom studied in ruminants (Cardot *et al.*, 2007).

II – Material and methods

This study was conducted at the Experimental Farm of the research Unit INRA-AgroParisTech MoSAR (Thiverval-Grignon, France (48°51' N; 1°55' E); 70 m above sea level). Four Alpine and four Saanen goats (160 DIM at the start of the experiment) were housed in individual pens with free access to feed and water. Goats were fed a total mixed ration (TMR) twice daily after milking, in the proportion of two thirds at 4 p.m. and one third at 8 a.m., according to the milking intervals. The ingredients of the diet, on a dry matter basis, were dehydrated lucerne (30%), meadow hay (20%), pressed sugar beet pulp (30%) and compound concentrate feed (20%).

Animals were weighed weekly. Individual amounts of feed offered and refusals were weighed daily. Intakes of feed and water were recorded separately using, for each animal, two weighing-scales (Balea, Saint-Mathieu de Tréviers, France): one was fitted under the feeding trough and the other one under a water container linked to the drinking trough. This system continuously recorded every 2 min the weight of the feed in the feeding trough and of the water in the container with a precision of 5 g. Cumulative dry matter intake (DMI) or water drunk (WD) per kilogram of body weight (BW) was calculated for the 22 hours following the afternoon feeding, using the body weight and the dry matter percentage of the diet (ISO, 1983) measured weekly. Animals had no access to food during the two remaining hours of the 24 h period (around afternoon milking). The evolution of the percentages of DMI and water drunk was studied during the nycthemere by 20-min intervals. The percentage of DMI or water drunk during the first three hours after the afternoon feed allowance was also calculated and called P180DMI and P180WD respectively, because it was the period during which the maximum of variability between goats was observed for food and water intakes (Giger-Reverdin *et al.*, 2011). The latency from the beginning of the afternoon meal to the first water intake was also calculated.

Two periods of five consecutive days were compared: the first one was between the 17^{th} and the 22^{th} of June 2010, and the second one between the 26^{th} of June and the 1^{st} of July 2010. Milk production was measured at each milking and averaged for 5 days. Milk samples were analysed for fat and protein contents at the beginning and end of each period. Blood samples were also analysed twice at each period for gas composition with a blood gas analyzer ABL77 (Radiometer®). Temperature (T in °C) and humidity (H %) were measured in the experimental facility at three times each day: 9 am, 1.30 pm and 5 pm (GMT + 2 h). The temperature-humidity index (THI) was calculated according to the formula of West (1994):

$THI = 0.81\ T + (H/100) * (T - 14.3) + 46.3.$

Data were analysed using the MIXED procedure of SAS® for repeated measurements with the following model: $Y_{ij} = \mu + P_i + G_j + P_i{*}G_j + \varepsilon_{ij}$

where μ represents the overall mean, P_i the period effect, G_j the goat effect. $P_i{*}G_j$ the interaction between the period and the goat effects.

The model included the repetition of the day within the period with the use of a mixed procedure First autoregressive AR(1). For the temperature and humidity data, the only effect tested was that of the period.

III – Results

1. Temperature and humidity in the goat unit

During both periods, the temperature increased during the day while the humidity decreased. However, the modifications were very small in the first period and more marked in the second one. This last period can be considered as a heat episode for the country with a mean temperature of 27.5°C at 5 pm (26.7 to 28.4°C) and a mean humidity of 41% (35 to 50%). The period effect was significant except for the humidity in the morning (Table 1).

Table 1. Temperature and humidity in the goat unit during Periods 1 (control) and 2 (heat stress)

	Time	Period 1	Period 2	SEM	Period effect
Temperature (°C)	9 am	17.0	21.3	0.52	0.001
	1.30 pm	18.0	25.4	0.56	<0.0001
	5 pm	19.0	27.5	0.41	<0.0001
Humidity (%)	9 am	66.4	64.8	1.32	NS
	1.30 pm	60.0	45.4	2.95	0.01
	5 pm	57.4	40.6	2.83	0.01

NS: not significant.

2. Feed and water intake

Dry matter intake (DMI) was not modified by temperature, but water intake increased by 40% when the temperature increased (Table 2). The percentage of dry matter intake during the first three hours after the afternoon feeding did not vary, but there was a decrease in the percentage of water drunk. All the goats started to eat before drinking. Moreover, the latency to the first water intake after feeding allowance decreased with the increase in temperature. Feeding behavior expressed as % DMI per 20min intervals was not modified by heat stress (Fig. 1).

Table 2. Feed and water intakes during Periods 1 (control) and 2 (heat stress)

	Period 1	Period 2	SEM	Effect		Interaction Period*Goat
				Period	Goat	
DMI[1]	47.1	47.2	0.36	NS	<0.0001	0.02
Water drunk[2]	107	143	2.3	<0.0001	<0.0001	0.004
P180DMI[3]	0.38	0.37	0.009	NS	NS	NS
P180WD[3]	0.41	0.35	0.012	0.01	0.001	NS
Latency before the first water intake[4]	35	26	1.5	0.001	<0.0001	NS

[1]in g per kg of body weight; [2]in ml per kg of body weight; [3]Proportion of the daily intake eaten (DMI) or drunk (WD) during the first 180 min after the afternoon feeding; [4]in min after the afternoon feeding; NS: not significant.

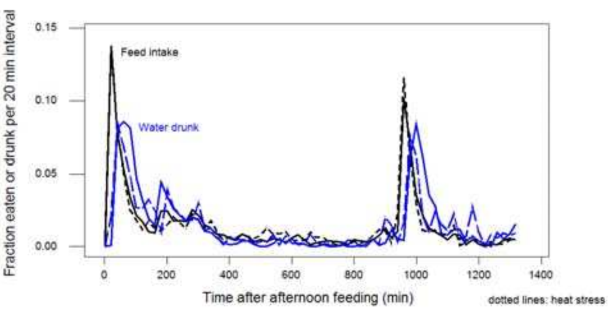

Fig. 1. Evolution of the quantities of water drunk and feed intake during the nycthemere.

3. Blood parameters

Blood PCO_2 decreased with the increase in temperature, whereas rectal temperature increased:

Table 3. Blood parameters and rectal temperature during Periods 1 (control) and 2 (heat stress)

	Period 1	Period 2	SEM	Effect		Interaction Period*Goat
				Period	Goat	
pH	7.39	7.40	0.004	0.04	0.001	NS
PCO_2 (mm Hg)	44.4	40.6	0.69	0.01	NS	NS
PO_2 (mm Hg)	35.6	36.6	1.12	NS	0.05	NS
Bicarbonates (mmol/L)	25.6	24.7	0.37	NS	NS	NS
Rectal temperature °C	38.5	39.1	0.07	<0.0001	NS	NS

NS: not significant

4. Milk production

Raw milk yield was not modified by heat stress, but the fat content and the fat yield decreased, (Table 4). Protein content and protein yield were not affected by the increase in temperature.

Table 4. Milk yield and composition during Periods 1 (control) and 2 (heat stress)

	Period 1	Period 2	SEM	Effect		Interaction Period*Goat
				Period	Goat	
Raw milk yield[1]	3.55	3.61	0.031	NS	<0.0001	0.03
Fat content[2]	33.3	30.2	0.31	<0.0001	<0.0001	0.01
Protein content[2]	31.9	31.3	0.09	0.01	<0.0001	NS
Fat yield[3]	116	108	1.7	0.01	0.001	NS
Protein yield[3]	113	113	1.0	NS	<0.0001	0.02

[1]in kg/day (mean of 5 days); [2]in g/kg of milk; [3]in g/day; NS: not significant.

5. Breed and goat effects

There was a breed effect on live-weight (Alpine: 58.3 kg *vs* Saanen: 64.2 kg; SEM = 0.52; $P < 0.001$) and intake: Alpine goats ate more dry matter per kg of body weight than Saanen (49.3 *vs* 45.9 g DMI/kg BW; SEM = 1.15; $P = 0.02$), and drank more water when expressed on a dry matter intake basis: 2.82 *vs* 2.46 L/kg DMI; SEM = 0.073; $P = 0.01$). The increase in this latter ratio with the temperature was more pronounced for the Alpine goats (Period 1: 2.38; Period 2: 3.26) than for the Saanen goats (Period 1: 2.15; Period 2: 2.76).

IV – Discussion

In this experiment, heat stress can be considered as a very moderate one, because the THI index was slightly above 72 during the afternoon in Period 2 which is the threshold level above which there is heat stress (West, 1994). It did not modify eating behavior on the contrary to other situations where goats were bred in harsh conditions (Silanikove, 2000). Nevertheless, total water intake was increased and the latency between the afternoon feeding and the first water intake was decreased, meaning that the animals felt thirsty earlier after TMR allowance

(Olsson *et al.*, 1997). The respiratory alkalosis (decrease in PCO_2) observed during Period 2 could be explained by the hyperventilation of the animals during the heat stress as already observed in cows (Kadzere *et al.*, 2002) or in goats (Augustinsson *et al.*, 1986). When the animals are panting, which is a way to decrease their inner temperature, they release CO_2. Although moderately heat-stressed, the experimental goats showed increased rectal temperature as previously observed in other animals exposed to hot periods (Augustinsson *et al.*, 1986; Kadzere *et al.*, 2002). The decrease in milk fat content has already been observed in dairy cows under a mild heat stress (Bandaranayaka and Holmes, 1976). The difference between breeds in terms of the water/DMI ratio might be explained by the higher level of intake of Alpine compared to Saanen goats and probably by a need to dissipate more heat from rumen fermentation (West, 1994; Kadzere *et al.*, 2002). It could also be due to the difference in coat colours: in Holstein cows, the temperature of the skin is higher in black areas than in white ones, leading to an increase in sweating rate in the black areas compared to the white ones (Da Silva and Maia, 2011). This could explain why Alpine goats with their dark-brown coat drank more water/kg DMI than the white coated Saanen goats.

V – Conclusion

High-producing European dairy goats seemed to cope well with short periods of moderate heat stress when water was available *ad libitum*. This study, which included feeding and drinking patterns, needs to be completed with a larger scale experiment and with measurements of the water fluxes and water losses *via* urine, faeces and milk. Long term adaptation and effects on production warrant future research in view of rampant global warming.

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