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SHORT WATER RESTRICTION EPISODE IN LACTATING ALPINE AND SAANEN GOATS

Lina S. Jaber,⁴⁸ Christine Duvaux-Ponter,^{49,50} Shadi K. Hamadeh⁴⁸ and Sylvie Giger-Reverdin^{49,50}

Abstract

This project aimed to assess the effect of a short episode of water restriction on high-producing lactating goats. Water was withheld from eight Saanen and eight Alpine goats from immediately after the afternoon milking until the following morning on two consecutive days. Water and feed intake, body weight and major blood parameters were assessed daily for a day before, during water restriction, and for two days after. Milk production and composition were also measured daily. The results showed that the animals experienced some dehydration as a result of the treatment, although they maintained a total water intake similar to the control values recorded on day 1. A drop in feed intake was observed on the days of water restriction, but body weight was not affected. Several blood indicators also pointed to the state of dehydration that the animals were experiencing: increases in albumin, urea, osmolality and sodium (Na⁺). The goats maintained milk production, but milk composition was altered: milk urea and lactose contents increased under water restriction thus keeping milk isotonic with the blood. The observed changes reflect the activation of mechanisms that limit body water loss and prevent further dehydration. It was concluded that high-producing goats were able to sustain two short consecutive cycles of dehydration and rehydration, as indicated by their maintained body weight and milk production, with only transient physiological and milk changes.

Key words: Alpine, Saanen, lactation, water restriction

Introduction

Goat production is an important economic activity in Europe and in rural areas around the world, where it is practised mostly under extensive systems with high dependence on natural resources and environmental conditions (Jaber, Chedid and Hamadeh, 2013). Heat waves and water shortages are becoming more common, including in Europe where temperate weather used to prevail. Goat breeds show great variability in their

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adaptations to these conditions. On the one hand, breeds that are native to arid and semi-arid regions have been well studied and show high resilience to heat and drought through special adaptive mechanisms that include high renal water retention, rapid water replenishment on rehydration with slow release into the bloodstream to prevent haemolysis, and minimization of water loss for evaporative cooling (Abdelatif, Elsayed and Hassan, 2010; Silanikove 2000; 1994). On the other hand, European breeds have rarely experienced these conditions in the past and are now being challenged in both their native countries and the countries to which they are exported because of their high productivity. This project aimed to assess the effect of two consecutive periods of water restriction on the physiology and production of Saanen and Alpine goats in mid-lactation raised in their native European climate.

Materials and methods

The experiment was conducted on the experimental farm of the research unit of IN-RA-AgroParisTech MoSAR (Thiverval-Grignon, France; 48° 51' N; 1° 55' E; 70 m above sea level). Eight Alpine and eight Saanen goats (160 days in milk [DIM] at the start of the experiment) were included. The animals were housed in metabolic cages and were well adapted to the experimental setting (including housing, feeding and human manipulation), which was applied from 20 days prior to the beginning of the experiment. The experiment lasted for five days during which water was offered ad libitum during the first day, withheld from immediately after the afternoon milking until the following morning on days 2 and 3 (15 hours of restriction), and offered ad libitum on days 4 and 5. The animals had free access to feed which was composed of dehydrated lucerne (30 percent on a dry matter basis), meadow hay (20 percent), pressed sugar beet pulp (30 percent) and compound concentrate feed (20 percent). The feed was offered ad libitum, making sure that 10 percent was left over; feed quantities were readjusted accordingly, on a weekly basis.

Individual water and feed consumption were measured daily, along with body weight, rectal temperature and milk production. For half of the goats, urine and faecal output was measured on the first three days of the experiment. Daily milk samples were analysed for fat, protein, lactose and urea content. Jugular blood samples were taken each morning, before offering fresh water and feed. A blood gas and mineral analyser (ABL 77, Radiometer, Copenhagen, Denmark) immediately determined sodium (Na⁺). Plasma was harvested and stored at -20 °C until assays for glucose, non-esterified fatty acids (NEFA), albumin and urea were carried out using a Cobas Mira-Analyzer (Roche, Mannheim, Germany) with commercial kits for glucose (Gluco-quant, Glucose/HK, Roche Diagnostic, Mannheim, Germany), NEFA (NEFA-HR[2], Wako, Chemical GmbH, Neuss, Germany), albumin (80002, Biolabo, 02160, Maizy, France) and urea (Urea/BUN, Roche Diagnostic, Mannheim, Germany). Osmolality was determined with a MARK3, radiometer analytical SA osmometer (manufactured by Fiske® Associates, Norwood, Massachusetts, United States of America) applying a method based on the depression in the critical freezing point. Environmental temperature and humidity were recorded three times a day.

The data were analysed by paired-t test using the IBM-SPSS Statistics 21 software. Day 1 was used as the control for each animal and was compared separately with each of the subsequent days of the experiment.

Results and discussion

The water restriction regime caused a significant decrease in water intake (Table 1) on the first day of restriction (day 2 of the experiment). However, on days 4 and 5, water consumption exceeded the control level. This could indicate a reaction of overcom-

pensation whereby the animals tend to drink large volumes of water in anticipation of future water shortage episodes. In this experiment, the water drunk in the morning straight after rehydration was more than twice the amount taken on the day of normal watering: 2.88 litres (normal) on day 1 versus 6.4 and 6.8 litres on days 2 and 3, respectively. Such behaviour was previously observed in arid-adapted breeds and denotes the capacity to tolerate rapid rehydration without risking haemolysis (Jaber et al., 2014; Silanikove, 1994). Another factor that could explain the increase in water consumption is the observed increase in ambient temperature during the experimental period, from 15.6 to 19.1 °C in the morning, and from 19.0 to 23.3 °C in the afternoon. This increase in ambient temperature was also reflected by higher rectal temperatures (Table 1), although the temperature range remained within the thermo-neutral zone of the animals (Giger-Reverdin and Gihad, 1991). The increase in water consumption may have been needed for cooling in response to the added heat load.

In contrast, the animals reduced their feed intake under water restriction (Table 1). This response is widely observed in small ruminants, which need water for proper digestive function (Hadjigeorgiou et al., 2000); it is thought that this is to prevent feed accumulation and compaction in the digestive tract. However, the animals' body weight seemed to increase throughout the experimental period, which may indicate that water consumption has a greater effect on body weight than feed consumption during the short term of this experiment.

TABLE 1. WATER AND FEED INTAKES, BODY WEIGHTS, RECTAL TEMPERATURES AND FAECAL AND URINE OUTPUTS OF LACTATING SAANEN AND ALPINE GOATS SUBJECTED TO TWO SUCCESSIVE 15-HOUR PERIODS OF WATER RESTRICTION

Parameter	Day 1	Day 2 ¹	Day 3 ¹	Day 4	Day 5
Water intake (litres)	7.26 ± 0.301	6.41 ² ± 0.301	6.85 ± 0.282	8.04 ² ± 0.359	8.32 ² ± 0.381
Feed intake (kg)	5.45 ± 0.129	5.02 ² ± 0.127	5.00 ² ± 0.134	5.29 ² ± 0.136	5.40 ± 0.140
Body weight (kg)	60.6 ± 1.82	61.4 ± 2.19	62.02 ± 1.86	63.12 ± 1.96	62.52 ± 1.99
Rectal temperature (°C)	38.54 ± 0.056	38.70 ² ± 0.044	38.80 ² ± 0.044	38.84 ² ± 0.050	38.83 ² ± 0.057
Wet faecal material output (kg)	3.30 ± 0.171	3.45 ± 0.209	3.45 ± 0.143		
Faecal material dry matter (%)	27.3 ± 0.71	29.2 ² ± 1.02	28.5 ² ± 0.69		
Urine output (litres)	1.11 ± 0.089	0.89 ² ± 0.089	1.25 ± 0.124		

1 Water removed directly after the afternoon milking until the next morning.

2 Means are significantly different from day 1 (P < 0.05)

Water restriction led to a decrease in urine output during the first day. In contrast, the faecal output was not significantly affected (Table 1), but faecal dry matter content increased. These observations indicate that the animals activated their water conservation mechanisms at the level of the kidneys and through the digestive tract, to minimize water loss and further dehydration. Highly adapted sheep breeds have been reported to produce very small amounts of highly concentrated urine when subjected to prolonged water restriction (Laden, Nehmadi and Yagil, 1987). The Alpine and Saanen goats of this experiment seem to show similar trends in short-term water restriction episodes.

The water restriction protocol applied in this experiment was effective in causing the physiological signs of dehydration as commonly reported in the literature (Table 2). The first sign was the increase in blood albumin observed on days 3 and 4, following water restriction and just before watering. This increase denotes a reduction in blood volume, whereby blood water may have been circulated to other body compartments to maintain normal function (Jaber et al., 2014; Mengistu, Dahlborn and Olsson, 2007). Blood Na⁺ and urea also increased under water restriction. Previous studies have indicated that increase in these parameters is a sign of the activation of water conservation at the level of the kidneys, as Na⁺ and urea reabsorption by the nephrons leads to water reabsorption (Mehta, 2008). This also explains the previously observed decrease in water urine output. The increase in blood electrolytes, in turn, causes an increase in osmolality, which is observed in this experiment as in the literature (Dahlborn, 1987; Mengistu, Dahlborn and Olsson, 2007). It is worth noting that osmolality, urea and albumin dropped slightly below the control levels on day 5, following 24 hours of rehydration. This could indicate that the animals maintained the over-drinking behaviour for one day after the water restriction episode, probably in anticipation of possible future restrictions. It was previously reported that small ruminants may show a slow return to normal blood composition on rehydration, although they ingest large volumes of water as an adaptation to prevent haemolysis (Jaber, Chedid and Hamadeh, 2013). The slightly lower values observed on day 5 indicate a return to normal blood volume, or perhaps more than normal blood volume because of the water influx from the rumen. It would be interesting to evaluate the blood rehydration status in relation to the urinary output in order to assess whether kidney function was restored simultaneously to rid the body of the excess water.

TABLE 2. BLOOD CHEMISTRY PARAMETERS IN LACTATING SAANEN AND ALPINE GOATS SUBJECTED TO TWO SUCCESSIVE 15-HOUR PERIODS OF WATER RESTRICTION

Parameter ¹	Day 1	Day 2 ²	Day 3 ²	Day 4	Day 5
Glucose (g/litre)	0.583 ± 0.0054	0.583 ± 0.0112	0.625 ³ ± 0.0167	0.612 ³ ± 0.0075	0.571 ± 0.0071
NEFA (mmol/litre)	137 ± 6.6	136 ± 6.4	133.00 ± 4.771	127 ± 3.3	125 ± 4.2
Urea (g/litre)	0.256 ± 0.0171	0.235 ± 0.0148	0.331 ³ ± 0.0169	0.397 ³ ± 0.0280	0.250 ± 0.0136
Albumin (g/litre)	43.43 ± 0.371	43.98 ± 0.358	46.04 ³ ± 0.523	44.61 ³ ± 0.382	42.78 ± 0.342
Osmolality (mOsm/kg)	294 ± 0.6	293 ± 0.7	306 ³ ± 0.9	307 ³ ± 0.7	2923 ± 0.5
Na ⁺ (mmol/litre)	142 ± 0.3	143 ³ ± 0.4	149 ³ ± 0.4	148 ³ ± 0.5	143 ± 0.3

1 Blood was sampled in the morning before offering feed and water.

2 Water removed immediately the afternoon milking until the next morning.

3 Means are significantly different from day 1 (P < 0.05).

The glucose and NEFA results (Table 2) seem to indicate a status of positive energy balance during water restriction although the animals decreased their overall feed intake. It could be speculated that the significant increase in glucose on days 3 and 4 is an indication of altered eating patterns by the thirsty animals, which caused the surge in glucose at the time of measurement, while under normal watering the animals would delay eating until fresh feed and water were offered. Previous reports on glucose levels under dehydration are inconclusive, but it is generally noted that a decrease in feed intake usually leads to a decrease in glucose levels (Jaber, Chedid and Hamadeh,

2013). Behavioural observations on the timing of feed intake under water restriction are needed to clarify the results obtained in this experiment. The NEFA tended to decline over the experimental period, further denoting that the animals were in positive energy balance (Jaber et al., 2011), which may also explain why no weight loss was observed.

Milk production was maintained under water restriction, with a slight surge in production on day 5 (Table 3), but lactose and urea tended to increase following water restriction on days 3 and 4. It was previously observed that lactose plays an important role in keeping the milk isotonic with the blood (Dahlborn, 1987). Therefore, in view of the increased blood urea, albumin and osmolality, the changes observed in milk composition are a reflection of changes in the blood. Similarly, the surge in production and the slight drop in major milk components on day 5 may be another reflection of a transient state of over-hydration as noted above, whereby the animals tended to produce a larger, but more dilute, volume of milk. Milk fat was not significantly affected by water restriction but seemed to decline slightly throughout the experimental period. Alamer (2009) reported a decrease in the fat content of milk in 25-percent water-restricted goats, while those that were 50-percent restricted maintained normal fat content. Longer-term experiments may be helpful in determining the effect of water restriction on milk composition of high-producing European goats.

TABLE 3. MILK PRODUCTION AND COMPOSITION OF LACTATING SAANEN AND ALPINE GOATS SUBJECTED TO TWO CONSECUTIVE 15-HOUR PERIODS OF WATER RESTRICTION

Parameter	Day 1	Day 2 ¹	Day 3 ¹	Day 4	Day 5
Milk production (litres)	3.61 ± 0.119	3.59 ± 0.108	3.57 ± 0.110	3.60 ± 0.110	3.73 ± 0.107
Milk fat (g/kg)	33.1 ± 1.07	33.0 ± 1.056	32.78 ± 1.137	32.3 ± 1.05	32.0 ± 0.87
Milk protein (g/kg)	31.9 ± 0.58	31.6 ² ± 0.56	31.8 ± 0.59	31.6 ± 0.46	31.5 ² ± 0.52
Lactose (g/kg)	43.8 ± 0.36	43.8 ± 0.37	44.6 ² ± 0.41	44.1 ± 0.45	43.5 ² ± 0.37
Milk urea (g/kg)	0.567 ± 0.0142	0.536 ² ± 0.0141	0.592 ± 0.0199	0.596 ± 0.0182	0.517 ² ± 0.0167

1 Water removed immediately after the afternoon milking until the next morning.

2 Means are significantly different from D1 (P < 0.05).

Conclusions

This experiment demonstrated the capacity of high-producing Alpine and Saanen goats to adapt to a short-term water restriction regime. Although signs of dehydration were observed, these signs were temporary and did not seem to affect the overall status of the animals, as attested by their maintained body weights and milk production. Longer-term studies would be interesting to assess the effect of such watering regimes over an extended period; in addition, behavioural data on water and feed intake would be helpful in explaining all aspects of these breeds' adaptability to water shortage.

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