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Mechanisms causing decreased milk production in water deprived goats

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SUMMARY - In this study four goats were investigated during 48 h of water deprivation. Milk production was 3.1 ± 0.2 l during control days and dropped to 2.2 ± 0.2 l after 24 h, and to 1.2 ± 0.1 l after 48 h of water deprivation. This corresponded to a 20% fall in milk vein blood velocity (MBV) the first day and a 40% decrease in MBV the second day. Plasma volume fell only from 2.8 ± 0.1 to 2.4 ± 0.3 l after 48 h water deprivation. This indicates a local regulation within the mammary gland. Plasma arginine vasopressin (AVP) increased from 1.3 ± 0.3 to 10.4 ± 1.7 pmol/l on the second day of water deprivation and it can not be excluded that AVP is involved in regulating the distribution of blood flow to the udder in the dehydrated goat. Total milk protein concentration fell during water deprivation which was shown to be caused by a decrease in the casein fraction.

Key words: Milk production, fluid balance, water deprivation, dairy goats.

***RESUME** - "Mécanismes qui causent une diminution de la production de lait chez des chèvres privées d'eau". Cette étude a porté sur quatre chèvres privées d'eau pendant 48 h. La production de lait était de 3,1 ± 0,2 l pendant les journées témoin et elle est tombée à 2,2 ± 0,2 l après 24 h, et à 1,2 ± 0,1 l après 48 h de privation d'eau. Ceci correspondait à une baisse de 20% dans le flux du sang dans la veine laitière (MBV) pendant le premier jour et à une baisse de 40% du MBV le deuxième jour. Le volume plasmatique n'a diminué que depuis 2,8 ± 0,1jusqu'à 2,4 ± 0,3 l après 48 h de privation d'eau. Ceci indique une régulation locale au sein de la glande mammaire. La vasopressine arginine du plasma (AVP) a augmenté depuis 1,3 ± 0,3 jusqu'à 10,4 ± 1,7 pmol/l lors du deuxième jour de privation d'eau et il n'est pas exclu que l'AVP soit impliquée dans la régulation de la distribution du flux sanguin vers la mamelle chez la chèvre déshydratée. La concentration totale en protéines du lait est tombée pendant la période de privation d'eau, ce qui semble être dû à une baisse de la fraction de caséine.*

***Mots-clés :** Production de lait, bilan des fluides, privation d'eau, chèvres laitières.*

Introduction

Fluid balance regulation is critical in milk producing animals since water is the major component in milk. High-yielding dairy cows and goats may have daily losses of up to 10% of their body water with the milk, and therefore they need to drink large amounts and have an increased water turnover.

In European goat breeds water deprivation reduced milk volume after 24 h (Dahlborn, 1987; Konar and Thomas, 1970). Many factors have been suggested to cause such a drop in milk production. Among these are decreased food intake and elevated plasma arginine vasopressin levels. In parallel to the decrease in milk volume, milk lactose and fat concentrations increased (Dahlborn, 1987). The milk protein concentration has been reported to drop during dehydration in both goats (Dahlborn, 1987) and cows (Little *et al.*, 1984) but the mechanism behind this is unclear.

Plasma volume decreases during water deprivation (Dahlborn, 1987) and this might lead to reduced mammary blood flow, which could be an alternative explanation to the drop in milk secretion. To investigate this hypothesis, changes in plasma volume and milk vein blood velocity (MBV) were followed in four lactating goats during water deprivation. In addition, alterations in milk protein concentration were measured.

Material and methods

Four goats, with a mean body weight of 57 ± 4 kg were used. Two goats were in their first lactation, and the other two goats in their sixth lactation. Milk production the week before the experiment started was 3.1 ± 0.2 l. The goats had free access to food throughout the experiment, and had a daily water intake of 6.7 ± 0.3 l. The goats were milked twice daily at 8.00 h and 16.00 h. Before water was withheld, control measurements were made for 24 h. Water was taken away at 12.30 h, and given back after 48 h. Blood samples for analysis of plasma osmolality and arginine vasopressine (AVP) were taken before each milking and in connection with plasma volume measurements.

Plasma volume was measured on the control day, on the second day of water deprivation, and on the day after rehydration. 10 mg of Evans blue (T-1824) dissolved in isotonic saline was injected intravenously and blood samples were taken before the injection, and 10 min, 20 min and 30 min after. Every morning after milking, MBV was measured with a non-invasive ultrasound Doppler-technique (Christensen *et al.,* 1989). Blood samples were analysed for osmolality by freezing point depression technique (Advanced Osmometer Inc., Roebling, Germany) and for AVP with a RIA-kit (Euro-Diagnostica, Apeldoorn, The Netherlands). Milk protein composition was measured with an infrared technique (Multispec, Shields Ltd., York, England).

Results

Milk volume decreased after 24 h to 2.2 ± 0.2 l, and this corresponded to a 20% fall in MBV (Fig. 1). After 48 h the milk volume dropped to 1.2 ± 0.1 l and MBV decreased with 40%. Plasma volume only fell from 2.8 ± 0.1 to 2.4 ± 0.3 l after 48 h water deprivation (Fig. 1). The two older goats seemed to have another strategy compared to the two goats that were in their first lactation. The older goats decreased their MBV and milk volume already during the first day, and their plasma volume was maintained after 48 h without water. The young goats had a high milk flow during the first 24 h of water deprivation. Later on they became more severely dehydrated as shown by a lower plasma volume and higher plasma osmolality (335 mosm/kg *vs* 319 mosm/kg).

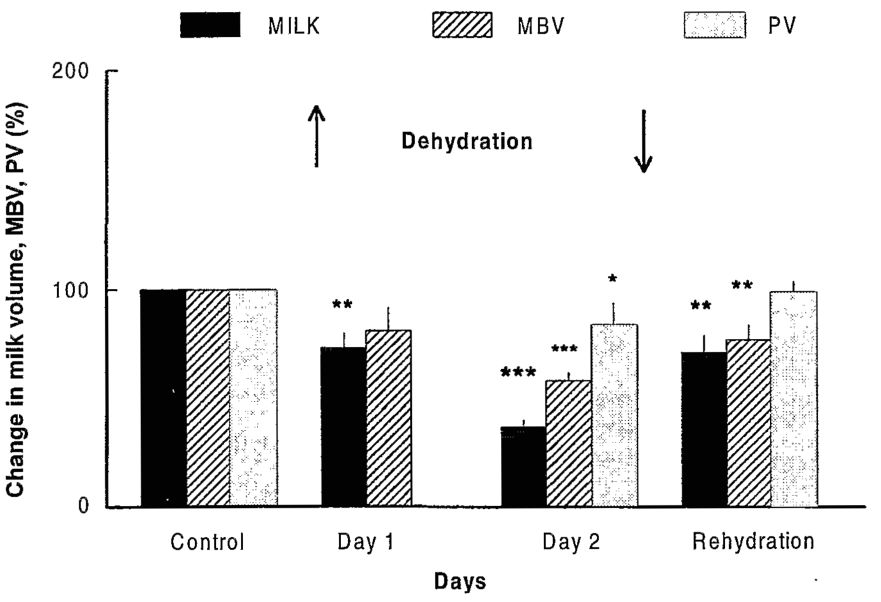

Fig. 1. Relative changes in milk volume, MBV and plasma volume in four goats during 48 h of water deprivation (arrows indicate when water was taken away and given back).

Plasma AVP increased from 1.3 ± 0.3 pmol/l to 2.5 ± 0.4 pmol/l on the first day and to 10.4 ± 1.7 pmol/l ($P<0.001$ *vs* control, n=4) on the second day of water deprivation. The change seen in total milk protein concentration during water deprivation was totally reflected by alterations in the casein fraction that is synthesized within the mammary gland, whereas the whey fraction did not change (Fig. 2).

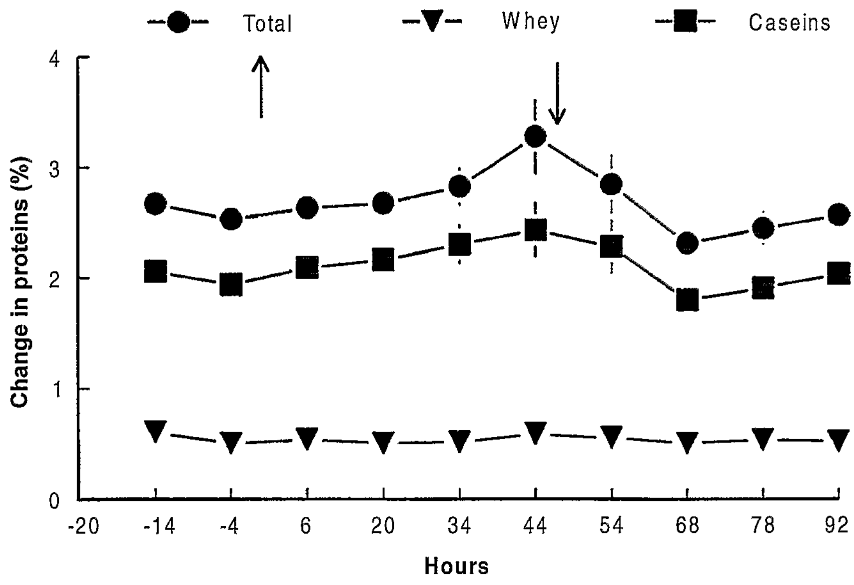

Fig. 2. Changes in total milk protein, whey protein and casein concentrations in four goats during 48 h of water deprivation (arrows indicate when water was taken away and given back).

Discussion

Water deprivation caused generally a decreased in food intake. It has been questioned whether the drop in milk secretion observed in dehydrated goats is due to the lack of water or to reduced food intake and its subsequent decrease of the mammary nutritional supply. In a experiment, the goats were fed the same amount of food they had consumed during water deprivation, but they had free access to water. Despite the reduction in food intake, milk production was only slightly affected (Dahlborn, 1987). Moreover, in the water deprived black Moroccan goat, the milk volume dropped although food intake was only slightly reduced (Hossaini-Hilali *et al.,* 1994). In addition, water deprivation alters milk composition differently compared to food deprivation (Annison *et al.,* 1968; Dahlborn, 1987). In the present study, the drop in milk volume following water deprivation was correlated to a decrease in mammary blood flow, and the reduction in MBV was not caused by a corresponding decrease in plasma volume. This is different to the drop seen in milk production during food deprivation, which is preceded by a similar decrease in both plasma volume and mammary blood flow (Chaiyabutr *et al.,* 1980). Taken together, these evidences indicate that the lack of water *per se* caused a reduction in milk yield.

Arginine vasopressin (AVP) has two well known effects in the body: at low levels it has an antidiuretic effect upon the distal segments of the renal tubular system, while at high levels it also acts as a vasoconstrictor. Whether AVP contribute or not to the decrease in milk secretion during water deprivation is equivocal. Konar and Thomas (1970) showed that intravenous infusions of AVP at pharmacological levels decreased the secretion of milk and suggested that elevated amounts of AVP could be the cause for the reduction in milk volume during dehydration. In contrast, short intravenous infusions of vasopressin to pressor levels in normo-hydrated goats did not alter milk secretion (Dahlborn *et al.,* 1990). In the present study the MBV was reduced before the rise in AVP concentration became markedly elevated. This does not exclude the possibility that AVP acts locally as a vasoconstrictor and reduced the mammary blood flow in the dehydrated goat.

In the study of Dahlborn *et al.* (1990) AVP was immunocytochemically detected in the mammary gland both after intravenous AVP infusions and after water deprivation, but not in control experiments. In addition, the cisternae of the rough endoplasmic reticulum in the secretory alveolar cells underwent significant swelling in response to the experimental procedures. This indicates that AVP might have a direct effect on the alveolar cells. The endoplasmic reticulum is the site where milk protein synthesis occurs, and we have earlier reported a drop in milk protein concentration during water deprivation (Dahlborn, 1987). This was shown here to be caused by an altered casein synthesis within the mammary gland. These are interesting findings, because recently similar morphological changes in the rough endoplasmic reticulum were reported to occur in goats bearing alleles associated with a reduced α_{s1}-casein content (Chanat *et al.,* 1996). These authors suggested that this can cause a slow down of the intracellular transport within the rough endoplasmic reticulum.

Conclusion

The drop in milk volume following water deprivation seems to be associated with a decrease in mammary blood flow. The reduction in MBV was not caused by a corresponding decrease in plasma volume. This indicates a local regulation within the mammary gland, a hypothesis supported by the observation that the decrease in milk protein content was due to an altered casein synthesis. Plasma AVP reached high levels and it can not be excluded that AVP is involved in regulating the distribution of blood flow to the udder in the dehydrated goat.

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