Water intake in dairy goats – the effect of different types of roughages

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Abstract

The aim of the current study was to investigate which type of roughage might influence the water intake in dairy goats. Eight goats were kept individually in single pens with one water bucket, with separated feeding table in order to register the drinking water intake, feed intake and milk yield for each goat. In experimental period 1 (3 days), four of the goats were fed hay and the remaining goats were fed silage, and vice versa in experimental period 2 (3 days). The goats drank more (P<0.0001) when they were eating hay compared to silage. Total water intake was higher (P<0.001) when they consumed silage than hay. The intake of silage was higher (P<0.001) than for hay, but the opposite for dry matter intake. In conclusion, roughage type had an effect on water intake, with higher drinking water intake when fed hay than silage, but the opposite was true for total water intake.

Introduction

There are several factors that influence the animal’s water intake and the most important ones are feed consumption (Kravy, 1984), dry matter (DM) content in the diet (Dahliborn et al., 1998), dry matter intake (DMI) (Andersson and Lindgren, 1987; Holter and Urban, 1992; Meyer et al., 2006), production status (Castle and Thomas, 1975; Meyer et al., 2004), body weight (BW) (Meyer et al., 2004; 2006) and ambient temperature (Meyer et al., 2004; 2006). Drinking water intake (DWI) has been reported to be positively correlated with both DMI (Andersson and Lindgren, 1987; Holter and Urban, 1992; Meyer et al., 2006) and milk yield (Castle and Thomas, 1975; Dewhurst et al., 1998). Paquay et al. (1970) found that the total water intake (TWI) (amount water drunk plus water derived from the diet) was positively correlated with DMI, but negatively correlated to the DM content in the diet.

The daily DWI in lactating dairy cows is measured to be around 3.8-4.7 L/kg DMI (Murphy et al., 1983; Holter and Urban, 1992; Cardot et al., 2008) when fed different diet mixes based on silage, and around 4.2 L/kg DMI when fed hay (Andersson and Lindgren, 1987). For lactating ewes given hay, the DWI is approximately 3.8 L/kg DMI (Forbes, 1968). Expressed in metabolic body weight (BW0.75), lactating cows drink 700-800 g/kg BW0.75 on silage based diets (Murphy et al., 1983; Meyer et al., 2004). There is negligible literature on water requirements in dairy goats, and most of them are studies from goats living in desert conditions under heat stress and/or water restrictions (Hossaini-Hilali et al., 1994).

Goats, especially breeds adapted to dry areas, have a more efficient renal system compared to other mammals and are capable of substitution between water drunk and water taken in with the feed (McGregor, 1986). Giger-Reverdin and Gihad (1991) have reported that goats living in temperate climates need 107 g/kg BW0.75 water at maintenance. Goats in their late pregnancy will increase their water intake by 40-50%, and it will reach around 165 g/kg BW0.75 for goats producing 148 g milk/kg BW0.75 at 10 weeks after parturition (Giger-Reverdin and Gihad, 1991).

In Norwegian goat milk production, silage is the most common roughage during the indoor season, but some farmers prefer to use hay as a feed supplement. Earlier experiments with lactating ruminants have investigated the effect of hay or silage on water intake (Forbes, 1968; Andersson and Lindgren, 1987; Cardot et al., 2008). The aim of this experiment was to investigate how type of roughage (hay or silage) might influence the water intake in dairy goats.

Materials and methods

Experimental design

A crossover design was performed, where 8 dairy goats were randomly divided into two experimental groups and fed two different kinds of roughage (hay and silage). In experimental period 1 (3 days) group 1 was fed hay and group 2 was given silage, and vice versa in experimental period 2 (3 days). Before each experimental period the goats had 7 days to adapt to the roughage type.

Experimental pens

The goats were held in an insulated, mechanically ventilated building where ambient temperature was kept around 12-14°C. Each goat was placed in a single pen with expanded metal floor and with a total area of 2.0 m². A water bucket (7.0 L) was located in a safety rack in every pen. Roughage was supplied on a separate feeding table for each pen in order to achieve recording of individual feed intake.

Animals and feeding

The eight goats of the Norwegian Dairy Goat breed were on average 3.3 year-old (range 2-4 years) and had a body weight of 58.5±1.7 kg (mean±SD). The goats were in the 19-25 week of lactation, with average milk yield of 3.9±0.4 kg (mean±SD).

The goats were fed roughage twice a day (07.00 and 15.00 h). To ensure ad libitum roughage feeding the goats were given hay or silage, equivalent to 120% of their calculated feed intake the previous day. In addition to the roughage, each goat was fed a daily amount of 1.2 kg of a commercial concentrate.

Recording of drinking water intake, feed intake and milk production

The goats were offered 5.0 L water in buckets twice a day at feeding time. Before filling up the bucket with new water, the remaining...
water was first weighed on an electronic balance (accuracy±10 g). Gross DWI was calculated by subtracting the amount remains of water from amount offered. TWI was calculated by adding the water content in the diet to amount of drinking water consumed.

Hay and silage were weighed on electronic balance before feeding time every morning and evening. Leftovers were collected and weighed, and the calculated feed intake was adjusted according to DM content both in feed samples and the leftovers.

Twice a day (08:00 and 16:00 h) the goats were milked in a milking parlour in an adjacent room and the milk yield for each goat was recorded.

**Roughage quality**

Samples from hay and silage and from every goat’s leftovers were taken every day during the two experimental periods. The roughage samples were analyzed for DM and ash described by Malkomesius and Nehring (1951). Content of total nitrogen (TN) was determined using the Kjeldahl method according to AOAC (1990), method 984.13. Content of crude protein (CP) was expressed as TN × 6.25. Neutral detergent fibre inclusive ash (aNDF) was determined using both sodium sulphite and heat stable amylase according to Van Soest et al. (1991). Crude fat were analyzed after hydrolysis of the samples with 3 M HCl, extraction with petroleum ether, distillation of the flout followed by drying and weighing of the residues. The nutritional value for the roughages (mean values for experimental period 1 and 2) and concentrate are presented in Table 1.

**Statistical analysis**

To analyze the effect of roughage type on water intake, analysis of variance using the mixed procedure (Littell et al., 1998) of SAS (1992) was performed. The measurements were repeated several times for each animal, and therefore a repeated measurement procedure was used. Random covariance structure proved useful for all data. To control possible carry over effects, sequence group (treatment x period interaction) was included in the model. Denominator degrees of freedom were adjusted according to the method described by Kenward and Roger (1997). Analysis of variance for repeated measurements was performed according to the following model:

\[
Y_{ijklm} = \mu + A_i + B_j + AxB_{ij} + C_k(B_j) + d(AxB_{ij}) + e_{ijklm}
\]

where:

- \(\mu\) is the intercept
- \(A_i\) is the fixed effect of roughage type, \(i = 1, 2\) (hay, silage)
- \(B_j\) is the fixed effect of experimental period, \(j = 1, 2\)
- \(AxB_{ij}\) is the interaction of roughage type \(i\) and experimental period \(j\)
- \(C_k(B_j)\) is the fixed effect of day within period, \(k = 1, 2, 3; j = 1, 2\)
- \(d(AxB_{ij})\) is the random effect of goat within
- \(e_{ijklm}\) represents the experimental error.

**Results**

DWI was significantly higher when fed hay compared to silage, whereas the TWI was significant higher for the goats consuming silage contra hay (Table 2). The daily DWI ranged from 2.9 to 9.2 litres when the goats were fed hay and for silage the corresponding value varied from 1.6 to 7.8 litres. Also the TWI showed a considerable variation as 3.2 to 9.8 and 5.1 to 11.0 L when fed hay and silage, respectively. However, there were no significant differences between the goats regarding DWI and TWI.

There was a significantly higher intake of silage than hay, but the BMI was significant higher for hay than silage (Table 2). The daily BMI ranged from 1.6 to 2.9 kg for hay and from 1.8 to 2.7 kg for silage. Goat number 3 in experimental period 1 had on the second day a very low intake of roughage; only 50 g hay on this particular day. This observation was therefore excluded from further calculations. DWI per kg BMI was significantly higher when the goats were fed hay compared to silage, whereas it was reversed for TWI/kg BMI (Table 2). Type of roughage had no significant effect on the goats’ milking yield, but to produce one kg milk the goats had to drink significant more water when they consumed hay compared to silage, while this was opposite for the TWI (Table 2).

There was no significant difference among the goats for none of the variables.

The water intake and milk production were significantly higher in experimental period 1

### Table 1. Nutritional values of the roughages and concentrate.

| Roughage       | Hay* | Silage* | Concentrate° |
|----------------|------|---------|--------------|
| Dry matter, %  | 82.4 | 25.3    | 87.0         |
| Crude protein, g/kg DM | 75.0 | 107.0  | 200.0        |
| Crude fat, g/kg DM | 12.0 | 23.0    | 101.0        |
| Neutral detergent fibre, g/kg DM | 590.0 | 580.0  | 224.0        |
| Ash, g/kg DM   | 46.0 | 65.0    | 79.0         |
| Starch, g/kg DM|       |         | 283.0        |

*Analysed, °calculated.

### Table 2. Daily intake of water, roughage intake, dry matter intake and daily milking yield (mean ± SE).

| Roughage Type | Hay | Silage | F_1,31 | P     |
|---------------|-----|--------|--------|-------|
| Drinking water intake, L/d | 6.2±0.3 | 4.4±0.3 | 46.5 | <0.0001 |
| Drinking water intake, L/kg DMI | 2.6±0.1 | 2.1±0.1 | 24.0 | <0.0001 |
| Drinking water intake, g/kg BW³⁵⁷ | 293.0±16.0 | 209.0±14.0 | 47.5 | <0.0001 |
| Drinking water intake, L/kg milk | 2.3±0.1 | 1.7±0.1 | 35.5 | <0.0001 |
| Total water intake, L/d | 6.6±0.4 | 7.9±1.3 | 19.9 | <0.0001 |
| Total water intake, L/kg milk | 3.2±0.8 | 5.1±1.1 | 16.0 | <0.0001 |
| Total water intake, g/kg BW³⁵⁷ | 2.8±0.1 | 3.6±0.1 | 39.5 | <0.0001 |
| Total water intake, g/kg BW³⁵⁷ | 314.0±16.0 | 373.0±15.0 | 19.4 | <0.0001 |
| Total water intake, L/kg milk | 2.5±0.1 | 3.1±0.1 | 22.8 | <0.0001 |
| Roughage intake, kg/d | 1.6±0.1 | 4.4±0.2 | 423.9 | <0.0001 |
| Dry matter intake, kg/d DM | 2.3±0.1 | 2.2±0.0 | 6.6 | <0.05 |
| Milk yield, kg/d | 2.7±0.1 | 2.6±0.1 | 2.4 | ns |

DMI, dry matter intake includes dry matter intake from both roughage and concentrate; BW, body weight; ns, not significant.
than in experimental period 2 (Table 3). However, no significant differences between the periods were found in TWI/kg milk, roughage intake and DMI (Table 3). Sequence group (treatment x period interaction) and day within period had no significant effect on none of the variables.

There was a significant, positive correlation between DWI and DMI when giving hay, but not for silage (Table 4). The DWI was positively correlated with milk yield for both roughage types (Table 4). DWI/kg BW0.75 was significantly higher when the goats ate hay contra silage (Table 2), and there was a positive correlation between DWI and body weight (kg BW0.75) for both roughage types (Table 4). For both roughage types, TWI was positively correlated to DMI (silage: R= 0.44, P<0.05; hay: R= 0.62, P< 0.01), milk yield (silage: R= 0.53, P<0.01; hay: R= 0.47, P<0.05) and BW0.75 (silage: R= 0.45, P<0.05; hay: R= 0.35, P<0.1). TWI was negatively correlated to DM content in the diet (both roughage types: R= -0.43, P<0.01), while DWI was positively correlated to DM content in the diet (both roughage types: R= 0.44, P<0.01).

### Discussion

The main results from this experiment showed that the goats’ DWI was higher when consuming hay than silage, while it was the opposite for the TWI.

The present experiment showed that the goats’ DWI was positively correlated with DMI for hay, but this was not true for silage. The wide range in DWI can be explained by the range in daily DMI. Correspondingly, DWI have been reported to be highly correlated to DMI in lactating cows (Little and Shaw, 1978; Holter and Urban, 1992) given diets with DM content over 50%. The low DM content in the silage based diet can be the reason why there was no correlation between DWI and DMI. Water consumption has been linked to diet DM concentration, and Castle and Thomas (1975) found a positive relationship between water drunk by lactating cows, their milk production, and the DM percentage of their diet. Previous studies have shown that goats have a more efficient renal system compared to other mammals (McGregor, 1986) and they do not need to drink if the dry matter content in the diet is less than 30%, but if water is available they will drink anyway (Giger-Reverdin & Gihad, 1991).

Consuming diets with a high DM content require a greater saliva secretion and a greater transfer of fluid across the rumen wall, leading to a reduction in amount of extracellular fluid. To maintain a normal osmolarity in the extracellular fluid when consuming a high amount of dry feed, the individual have to increase its DWI (Dahlborn, 1987). Animals eating a fibre rich diet have to consume more water due to the higher loss of faecal water (Paquay et al., 1970). The fibre content in the two experimental diets was identical, but due to a higher DMI in the group fed hay, these goats had a slightly higher fibre intake per day compared to the silage group.

The DMI from the silage diet was more correlated to TWI than DWI, whereas the corresponding value for the hay diet was almost the same for both TWI and DWI. Similar to the results of Paquay et al. (1970), there was a negative correlation between TWI and DM content in the diet. It has been suggested that increased urinary water loss, from greater urinary excretion of N and K for wet diets, may account for this result (Paquay et al., 1970). Similar have also been found that a higher CP content in the diet have shown to stimulate the water intake (Forbes, 1968; Holter and Urban, 1992). Murphy (1992) summarised this as; when the DM content in the diet increases, the DWI will increase, but the TWI will decrease.

The results showed that there was a positive relationship between DWI and body weight (kg BW0.75), and this is in agreement with earlier studies on cattle (Meyer et al., 2004; 2006). Giger-Reverdin and Gihad (1991) have reported that lactating goats have a TWI on 165 g/kg BW0.75 for a milk production on 146 g/kg BW0.75. This is lower than found in this experiment on both roughage types, even though the milk production was almost the same. It can be deducted that this difference might be influenced by differences in breed and/or ambient temperature.

### Conclusions

According to Giger-Reverdin and Gihad (1991), physiological status and level of production is important factors for water intake and they report that goats consume 1.28 kg of water for each kg of milk produced. This is lower than the TWI/kg milk we found in the present experiment on both diets. Interestingly, cows have a TWI around 2.6-3.3 l of water to produce one kg milk on a diet consisting of silage and concentrates (Holter and Urban, 1992; Dewhurst et al. 1998). The milk yield was positively correlated with DWI and TWI for both roughage types, and this is in agreement with earlier studies with dairy cows (Castle and Thomas, 1973; Dewhurst et al., 1998; Meyer et al., 2004). The water intake in

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**Table 3. Water intake, roughage intake and dry matter intake and milk production in the experimental periods (mean ± SE).**

| Experimental period 1 | Experimental period 2 | F<sub>1,33</sub> | P       |
|-----------------------|-----------------------|-----------------|---------|
| Drinking water intake, L/d | 5.9±0.4              | 4.7±0.3         | 20.1    | <0.0001 |
| Drinking water intake, L/kg DMI | 2.6±0.2           | 2.1±0.1         | 15.4    | <0.001  |
| Drinking water intake, g/kg BW<sup>0.75</sup> | 278.0±20.0         | 223.0±12.0      | 21.1    | <0.0001 |
| Drinking water intake, L/kg milk | 2.1±0.2          | 1.9±0.1         | 4.2     | <0.05   |
| Total water intake, L/d | 7.9±0.4              | 6.7±0.3         | 18.4    | <0.001  |
| Total water intake, L/kg DMI | 3.5±0.2             | 3.0±0.1         | 15.6    | <0.001  |
| Total water intake, L/kg milk | 374.0±17.0         | 315.0±14.0      | 18.1    | <0.001  |
| Roughage intake, kg/d | 3.1±0.3              | 3.0±0.3         | 0.2     | ns      |
| Dry matter intake, kg/d DM | 2.3±0.1            | 2.2±0.1         | 0.6     | ns      |
| Milk yield, kg/d | 2.8±0.1              | 2.5±0.1         | 31.6    | <0.0001 |

ns, not significant.

**Table 4. Correlation between drinking water intake and dry matter intake, body weight or milk yield when consuming hay and silage.**

| Drinking water intake | Hay, R and P values | Silage, R and P values |
|-----------------------|---------------------|-----------------------|
| Dry matter intake, kg | 0.59                | 0.07                  |
| Body weight, kg BW<sup>0.75</sup> | 0.37               | 0.41                  |
| Milk yield, kg | 0.47                | 0.58                  |

ns, not significant.
experimental 2 was lower than in experimental period 1 and this can be explain by the natural decease in lactation curve after the production peak.

In conclusion, type of roughage had an effect on the goats’ water intake in that they have a significantly higher DWI when fed hay than silage, whereas the opposite was true for TWI. When fed diets with high DM content, the DWI can reach up to 10 L per day, which shows the importance of an adequate water supply in order to achieve a high milk production.

References

Andersson, M., Lindgren, K., 1987. Effects of restricted access to drinking water at feeding, and social rank, on performance and behavior of tied-up dairy cows. Swed. J. Agr. Res. 17:77-83.

AOAC, 1990. Official Methods of Analysis. 15th ed., Arlington, VA, USA.

Cardot, V., Le Roux, Y., Jurjanz, S., 2008. Drinking behavior of lactating dairy cows and prediction of their water intake. J. Dairy Sci. 91:2257-2264.

Castle, M.E., Thomas, T. P., 1975. Water intake of British Friesian cows on rations containing various forages. Anim. Prod. 20: 181-189.

Dahlborn, K., 1987. Effects of temporary food or water deprivation in the lactating goat. Degree Diss., Swedish University of Agricultural Sciences, Upsala, Sweden.

Dahlborn, K., Åkerlind, M., Gustafson, G., 1998. Water intake by dairy cows selected for high and low milk-fat percentage when fed two forage to concentrate ratios with hay and silage. Swedish J. Agr. Res. 28:167-176.

Dewhurst, R.J., Offer, N.W., Thomas, C., 1998. Factors affecting water intake of lactating dairy cows offered grass silages differing in fermentation and intake characteristics. Anim. Sci. 66:543-550.

Forbes, J.M., 1968. Water intake of ewes. Brit. J. Nutr. 22:33-43.

Giger-Reverdin, S., Gihad, E.A., 1991. Water metabolism and intake in goats. In: P. Morand-Fehr (ed), Goat Nutrition. EAAP Publ. N. 46, Pudoc Wageningen, The Netherlands, pp 37-45.

Holter, J.B., Urban, W.E., 1992. Water partitioning and intake prediction in dry and lactating Holstein cows. J. Dairy Sci. 75:1472-1479.

Hossaini-Hilali, J., Benlamlih, S., Dahlborn, K., 1994. Effects of dehydration, rehydration, and hyper hydration in the lactating and non-lactating black Moroccan goat. Comp. Biochem. Physiol. A 109:1017-1026.

Kenward, M. G., Roger, J. H., 1997. Small Sample Inference for Fixed Effects from Restricted Maximum Likelihood. Biometrics 53:983-997.

Kraly, F. S., 1984. Physiology of drinking elicited by eating. Psychol. Rev. 91:478-490.

Littell, R.C., Henry, P. R., Ammerman, C. B., 1998. Statistical analysis of repeated measures data using SAS procedures. J. Anim. Sci. 76:1216-1231.

Little, W., Shaw, S.R., 1978. A note on the individuality of the intake of drinking water by dairy cows. Anim. Prod. 26:225-227.

Malkomesius, P.E., Nehring, K., 1951. Chemische Untersuchung von Futtermitteln. Page 15 in: R. Herrmann (ed) Handbuch der landwirtschaftlichen Versuchs- und Untersuchungs metho dik (Methodenbuch), Band III, Neumann Verlag, Berlin, Germany.

McGregor, B. A., 1986. Water intake of grazing Angora wether goats and Merino wether sheep. Aust. J. Exp. Agr. 26:639-642.

Meyer, U., Everingham, M., Gadeken, D., Flachowsky, G., 2004. Investigations on the water intake of lactating dairy cows. Livest. Prod. Sci. 90:117-121.

Meyer, U., Stahl, W., Flachowsky, G., 2006. Investigations on the water intake of growing bulls. Livest. Sci. 103:186-191.

Murphy, M.R., 1992. Symposium: Nutritional factors affecting animal water and waste quality – water metabolism of dairy cattle. J. Dairy Sci. 75:326-333.

Murphy, M. R., Davis, C. L., McCoy, G. C., 1983. Factors affecting water consumption by Holstein cows in early lactation. J. Dairy Sci. 66:35-38.

Paquay, R., de Baere, R., Lousse, A., 1970. Statistical research on the fate of water in the adult cow. J. Agr. Sci. 75: 251-255.

SAS, 1992. SAS/STAT Software: Changes and Enhancements Release 6.07. SAS Inst., Inc., Cary, NY, USA.

Snedecor, G. W. M., Cochran, W. G., 1989. pp 503 in Statistical Methods. 8th ed. Iowa State University Press, Ames, IA, USA.

Van Soest, P.J., Robertson, J.B., Lewis, B., 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition J. Dairy Sci. 74:3583-3597.