# Water intake and consumption in sheep differing in growth potential and adaptability

S.J. Schoeman* and J.A. Visser
Department of Animal and Wildlife Sciences, University of Pretoria, Pretoria, 0002 Republic of South Africa

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Water intake, efficiency and consumption of 30 growing individually fed Blackhead Persian, Dorper and South African Mutton Merino (Mutton Merino) ewe lambs were investigated. Average daily water intakes were 2.2, 4.6 and 5.4 litre for the Blackhead Persian, Dorper and Mutton Merino, respectively. The Blackhead Persian was 53% and 77% more efficient (water intake/kg weight gain) than the Dorper and Mutton Merino, respectively. By means of the allometric-autoregressive model, efficiency was separated into three distinctive phases. The Blackhead Persian furthermore consumed only 1.81 litre/kg feed compared to the 2.56 and 3.05 litre/kg feed of the Dorper and Mutton Merino, respectively.

Waterinname, -doeltreffendheid en -verbruik van 30 groeiende individueel gevoerde Swartkoppersie-, Dorper- en Suid-Afrikaanse Vleismerino-ooilammers (Vleismerino) is ondersoek. Gemiddelde daaglikse waterinnames was 2.2, 4.6 en 5.4 liter onderskeidelik vir die Swartkoppersie, Dorper en Vleismerino. Die Swartkoppersie was 53% en 77% meer doeltreffend (waterinname/kg gewigstoename) as onderskeidelik die Dorper en Vleismerino. Met behulp van die allometriese-outoregressiewe model kon die doeltreffendheid in drie duidelik onderskeibare fases verdeel word. Die Swartkoppersie het verder slegs 1.81 liter/kg voer verbruik vergeleke met die 2.56 en 3.05 liter/kg voer van onderskeidelik die Dorper en Vleismerino.

**Keywords:** Consumption, efficiency, sheep, water.

* To whom correspondence should be addressed at present address: Department of Animal Sciences, University of Stellenbosch, Stellenbosch, 7600 Republic of South Africa

## Introduction

In many countries of the world, and especially in parts of Africa, water is limited. The most effective way to maximize productivity in such semi-desert and areas of water restriction, would be to select breeds which are more adaptable to such conditions and therefore less dependent on water intake for normal production (Frisch & Vercoe, 1977; 1984).

In the past there has been considerable interest in differences in feeding behaviour, requirements and efficiencies between species and breeds. It is, however, well known that desert-adapted ruminants are more likely to utilize their water reservoir more efficiently and consequently enable them to maintain their appetite and production potential more effectively under heat stress conditions (Degen & Shkolnik, 1978; Silanikove, 1987). However, little is known about differences between breeds within species as far as water efficiency is concerned.

The objective of this study was to assess the relationships between body weight, feed intake and water intake in three sheep breeds, representing temperate (South African Mutton Merino), intermediate (Dorper) and desert (Blackhead Persian) types.

## Materials and methods

Ten randomly selected single-born ewe lambs each of the Blackhead Persian, Dorper and South African Mutton Merino (Mutton Merino) breeds were housed indoors in metabolic cages from 90 days of age for a period of 34 weeks (October 1990 to June 1991). To avoid obesity they were exercised daily in the morning by running approximately 800m.

The lambs were individually fed a pelleted balanced commercial diet with a ME value of 10.3 MJ/kg DM and a crude protein content of 150 g/kg DM. They were fed daily *ad libitum* and left-overs were removed weekly. Water was also individually available *ad libitum*.

Individual intakes of both feed and water were recorded weekly. A measured amount of water was provided daily. The amount of water consumed was determined by subtracting weekly evaporation losses, measured from a trough similar to those provided for the lambs, from the amount of water provided. Lambs were also weighed weekly after fasting overnight. Cumulative feed intake, feed efficiency, cumulative water intake, water efficiency and water consumption values between breeds were tested by means of analysis of variance.

For the purpose of fitting these relationships, the allometric-autoregressive model was used (Roux, 1974; 1976). This model has proved to be useful in the characterization of growth studies where input was also taken into account (Meissner, 1977; Roux & Kemm, 1981; Scholtz & Roux, 1981a, 1981b).

Individual as well as average relationships between ln (cumulative water intake) and ln (body weight) were estimated with

$$\ln y = \ln a + b \ln X$$

where

y = body weight
X = cumulative water intake
b = slope
a = intercept

Breakpoints in the relationships were obtained by fitting both the allometric and autoregressive plots. By applying this procedure, the growth period was separated into three distinct

phases, each describing a straight line in terms of slope and intercept.

Regression equations were then fitted for each animal by using simple regression procedures (SAS, 1991). Differences between intercepts and slopes for each phase were tested by means of a one-way analysis of variance.

## Results and discussion

Body weights, weight gain, means for cumulative feed and water intakes, feed and water efficiencies and water consumption between the three breeds are presented in Table 1.

Cumulative feed intake was 48% and 45% and body weight gain 36% and 38% higher in the Dorper and Mutton Merino than in the Blackhead Persian, respectively ($P \leq 0.05$). Feed efficiency was, however, not different between the three breeds ($P > 0.05$). Both differences in feed intake and growth rate were probably related to body size only (Thonney *et al.*, 1987).

Cumulative water intake differed ($P \leq 0.05$) between the three breeds, with that of the Dorper and Mutton Merino 109% and 145% higher than in the Blackhead Persian, respectively. Average daily water intake varied from 2.2 to 5.4 litres per day between the three breeds. At the start of the experiment (summer), daily water intake per kg of body weight varied from 9.2% in the Blackhead Persian to 15.6% in the Mutton Merino, with the Dorper being intermediate. Corresponding values at the end of the experiment (winter) were 3.8%, 4.2% and 6.3% for the Blackhead Persian, Dorper and Mutton Merino, respectively. According to the literature,

**Table 1** Starting and final weights, cumulative feed and water intake, feed and water efficiency and water consumption and body weight gain in Blackhead Persian, Dorper and Mutton Merino lambs (means ± SD)

| | Blackhead Persian | Dorper | Mutton Merino |
|---|---|---|---|
| Number of lambs | 10 | 10 | 10 |
| Starting body weight (kg) on 1990-10-26 | 190 ± 1.07[a] | 33.4 ± 1.64[b] | 28.2 ± 1.44[c] |
| Final body weight (kg) on 1991-06-13 | 49.1 ± 1.14[a] | 74.3 ± 2.17[b] | 69.8 ± 2.19[b] |
| Body weight gain (kg) | 30.1 ± 4.68[a] | 40.9 ± 3.96[b] | 41.6 ± 3.86[b] |
| Cumulative feed intake (kg) | 290 ± 29.1[a] | 429 ± 36.0[b] | 421 ± 22.4[b] |
| Feed efficiency (kg feed intake/kg weight gain) | 9.8 ± 1.10[a] | 10.5 ± 0.65[a] | 10.2 ± 0.85[a] |
| Cumulative water intake (litre) | 523 ± 54.7[a] | 1095 ± 104.6[b] | 1283 ± 169.1[c] |
| Water efficiency (water intake/kg weight gain) | 17.6 ± 1.98[a] | 26.9 ± 1.84[b] | 31.1 ± 2.73[b] |
| Water consumption (litre/kg feed intake) | 1.81 ± 0.223[a] | 2.56 ± 0.197[b] | 3.05 ± 0.414[c] |

[a,b,c]Means within rows with a common superscript do no differ significantly (P≤0.05)

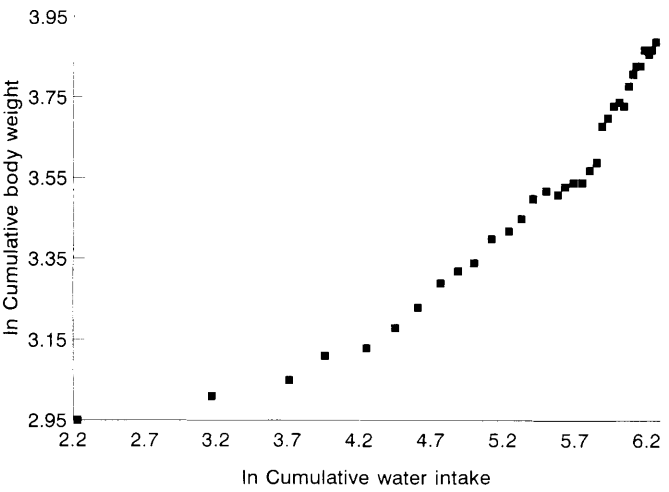


**Figure 1** Regression of ln cumulative body weight on ln cumulative water intake of a single Blackhead Persian lamb

daily water intake normally varies from approximately 5% to 20% of body weight (Adegbola & Obioha, 1984) and is influenced by breed (Quick & Dehority, 1986; El-Nouty *et al.*, 1988; Silanikove, 1989), sex (Rathore, 1987), temperature (McGregor, 1986) and production status (Maltz *et al.*, 1982).

Although feed efficiency did not differ between the three breeds, they differed in water efficiency ($P \leq 0.05$). The Blackhead Persian was the most efficient. The Dorper and Mutton Merino respectively consumed 53% and 77% more water per kg of body weight gain than the Blackhead Persian. The Blackhead Persian is therefore probably capable to balance its water requirements at a more economical level than the other two breeds. One would have expected the Dorper to be more efficient in this regard, since it was developed from the Blackhead Persian and adapted to desert-like conditions.

The allometric-autoregressive growth model (Roux, 1976), with ln (body weight) as a function of output on ln (cumulative water intake) as a function of input, is presented in Figure 1 and ln (cumulative water intake) at time (t) on ln (cumulative water intake) at time (t-1) in Figure 2 for a single Blackhead Persian lamb, demonstrating three distinct phases.

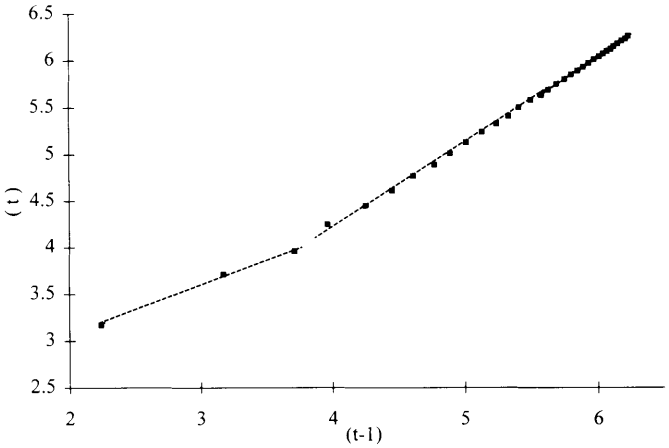


**Figure 2** Autoregressive relationship of ln cumulative water intake at time (t) on n cumulative water intake at time (t-1) of a single Blackhead Persian lamb

**Table 2** Regression equations, model parameters and analysis of variance for intercept and slope of the allometric-autoregressive growth model with water intake as input function

| **Phase 1** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Equations (± SE) | | | | P(b) | | $R^2$(%) | |
| Blackhead Persian: | $Y = 2.71^a + 0.098\ X$ (± 0.051) (±0.0145) | | | 0.007 | | 93.83 | |
| Dorper: | $Y = 3.13^b + 0.103\ X$ (± 0.104) (±0.0237) | | | 0.048 | | 90.57 | |
| Mutton Merino: | $Y = 3.00^b + 0.093\ X$ (± 0.255) (±0.0617) | | | 0.373 | | 69.55 | |
| | Intercept | | | | Slope | | |
| Source of variation | df | MS | F | P | MS | F | P |
| Between breeds | 2 | 0.2886 | 4.13 | 0.027 | 0.0012 | 0.84 | 0.544 |
| Within breeds | 27 | 0.0698 | | | 0.0014 | | |
| **Phase 2** | | | | | | | |
| Equations (± SE) | | | | P(b) | | $R^2$(%) | |
| Blackhead Persian: | $Y = 1.84^a + 0.303\ X$ (± 0.029) (±0.0056) | | | 0.000 | | 99.53 | |
| Dorper: | $Y = 2.40^b + 0.252\ X$ (± 0.252) (±0.0069) | | | 0.000 | | 99.04 | |
| Mutton Merino: | $Y = 2.25^b + 0.255\ X$ (± 0.035) (±0.0058) | | | 0.000 | | 99.19 | |
| | Intercept | | | | Slope | | |
| Source of variation | df | MS | F | P | MS | F | P |
| Between breeds | 2 | 0.3205 | 5.11 | 0.013 | 0.0017 | 1.44 | 0.254 |
| Within breeds | 27 | 0.0627 | | | 0.0012 | | |
| **Phase 3** | | | | | | | |
| Equations (± SE) | | | | P(b) | | $R^2$(%) | |
| Blackhead Persian: | $Y = -0.321 + 0.675\ X$ (± 0.2127) (±0.0350) | | | 0.000 | | 96.87 | |
| Dorper: | $Y = -0.319 + 0.540\ X$ (± 0.1288) (±0.0189) | | | 0.000 | | 98.31 | |
| Mutton Merino: | $Y = -0.354 + 0.642\ X$ (± 0.1469) (±0.0210) | | | 0.000 | | 98.73 | |
| | Intercept | | | | Slope | | |
| Source of variation | df | MS | F | P | MS | F | P |
| Between breeds | 2 | 2.69 | 1.61 | 0.219 | 0.0749 | 1.89 | 0.170 |
| Within breeds | 27 | 1.67 | | | 0.0396 | | |

[a,b]Intercepts with different superscripts between breeds differ significantly ($P \leq 0.05$)

Model parameters and analysis of variance for intercepts and slopes for the three breeds are shown in Table 2.

Intercepts differed in the first two phases ($P$ = 0.027 and 0.013 respectively), but not in the third phase ($P$ = 0.219). There was, however, no evidence of any difference between slopes in any one of the three phases ($P$ = 0.544, 0.254 and 0.170 for the three phases, respectively). Large differences in water efficiency between the Blackhead Persian on the one side and the Dorper and Mutton Merino on the other side (Table 1) were therefore the result of corresponding differences in intercepts and not due to differences in slopes. This is contrary to what was found in feed efficiency, where slopes of the allometric-autoregressive model were positively correlated to feed efficiency (Scholtz *et al.*, 1990).

There is normally a close relationship between the amount of water and the amount of food consumed by herbivores (Siebert, 1971; Macfarlane & Howard, 1972; More *et al.*, 1983; Hamilton & Webster, 1987). Increased feed intake stimulates water intake. Water consumption differed ($P \leq 0.05$) between the three breeds (Table 1). The Dorper consumed 41% and the Mutton Merino 68.5% more water per kg feed intake than the Blackhead Persian. A 22% difference in water intake/DM intake between woolly and hairy sheep was also obtained by Quick & Dehority (1986) who reported values which varied from 2.3 to 2.8 litre/kg DM.

The regressions of cumulative water intake on cumulative feed intake of the three breeds are presented in Figure 3 with model parameters and analysis of variance in Table 3.

No clear breakpoints were evident, except perhaps for the Mutton Merino at the 20th week. Quadratic relationships were fitted with $R^2$ values which varied from 99.81% to 99.96% and clearly demonstrated the higher water consumptions of the Mutton Merino and Dorper compared to the Blackhead Persian. Both intercepts and slopes varied significantly ($P \leq 0.05$). Differences in water consumption varied from 1.81 litre/kg feed for the Blackhead Persian to 3.05 litre/kg feed for the Mutton Merino. The changes in the slopes, which took place in all three breeds after approximately 20 weeks, were possibly associated with a decrease in temperatures (end of February).

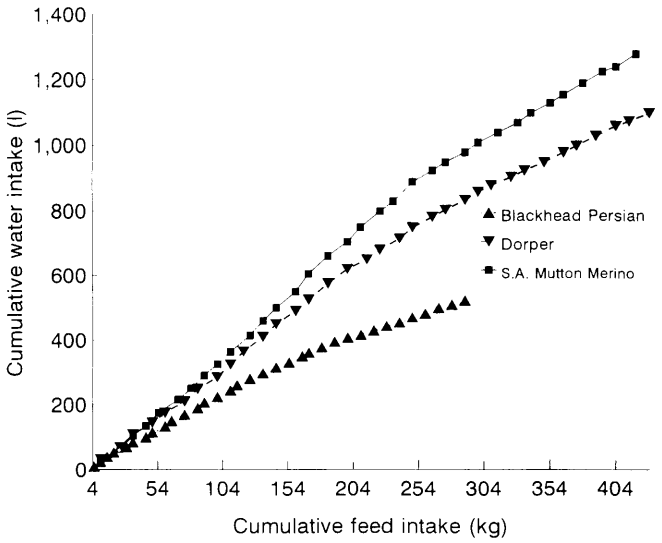


**Figure 3** Regressions of cumulative water intake on cumulative feed intake for Blackhead Persian, Dorper and S.A. Mutton Merino ewe lambs

## Conclusions

In this experiment large differences were demonstrated between the three breeds in water efficiency and consumption. The much lower water demand of the desert-adapted Blackhead Persian is evident.

Although the reasons for these differences were not investigated, it is believed that differences in the efficiency of the

**Table 3** Regression equations, model parameters and analysis of variance for intercept and slopes of the quadratic regressions of cumulative water intake on cumulative feed intake

| | Equations (± SE) | P(model) | $R^2$(%) |
|---|---|---|---|
| Blackhead Persian: | $Y = -5.1^a + 2.57^a X - 0.003 X^2$ (± 1.54) (±0.026) (±0.0001) | 0.001 | 99.96 |
| Dorper: | $Y = -30.7^b + 3.66^b X - 0.002 X^2$ (± 5.87) (±0.062) (±0.0001) | 0.001 | 99.90 |
| Mutton Merino: | $Y = -85.1^c + 4.35^c X - 0.003 X^2$ (± 9.31) (±0.102) (±0.0002) | 0.001 | 99.81 |

| | | Intercept | | | Slope 1 | | | Slope 2 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Source of variation | df | MS | F | P | MS | F | P | MS | F | P |
| Between breeds | 2 | 11477.7 | 41.6 | 0.0001 | 10.3 | 75.0 | 0.0001 | $2.2 \times 10^{-6}$ | 4.7 | 0.018 |
| Within breeds | 27 | 276.0 | | | 0.14 | | | $4.7 \times 10^{-7}$ | | |

[a,b,c]Intercepts and slopes with different superscripts between breeds differ significantly (P≤0.05)

renal system (Macfarlane & Howard, 1972), which reduces water loss, may provide a logical explanation. Lower energy requirements of desert-adapted breeds (Schmidt-Nielsen, 1964; Macfarlane *et al.*, 1971) and lower metabolic rates are also possibly related to such lower water requirements (Silanikove, 1989).

The experiment demonstrated that the Blackhead Persian apparently also balances its water requirements at a more economical level under temperate conditions. It makes this breed, but probably also other indigenous breeds, a more suitable choice under conditions of water scarcity.

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