U. of K. J. Agric. Sci. 18(3), 402-421, 2010

Digestibility Coefficients, Some Blood and Rumen Metabolites and Physiological Responses in Sudan Nubian Goats Subjected to Varying Levels of Feed and Water Restrictions

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Abstract: Three yearling uncastrated males of Sudan Nubian goats ranging in weight between 14 and 20 kg were used in a 3x3 latin square design experiment with the objective of studying the effects of feed and water restriction on dry matter intake (DMI), water intake, digestibility of nutrients, rumen components, blood urea-N (BUN), rectal temperature and respiration rate. The experiment consisted of three treatments: *Adlibitum* feed and water, feed restricted to 50% of *adlibitum* level with adlibitum water, water restricted to 50% of *adlibitum* level with *adlibitum* feed. The results revealed no significant treatment effects on water intake, urine volume, rectal temperature and respiration rate. However, DMI differed significantly between treatments. The *adlibitum* provision of water resulted in insignificant higher water intake compared with the other two treatments. Rectal temperature was higher in water restricted goats than in feed restricted goats, whereas respiration rate decreased insignificantly with both feed and water restrictions. Feed and water restrictions had no effect on the digestibility coefficients of the various nutrients. Water restricted goats showed, however, different trends except for ether extract digestibility which tended to decrease. Treatment had no significant effect on the total digestible nutrients (TDN) values. The TDN tended to be higher with water restriction. There was no significant treatment effect on rumen pH, ammonia-N (NH_3-N) and BUN. Feed and water shortage did not significantly affect digestibility of the proximate components but tended to slightly affect rumen metabolites, BUN, respiration rate and rectal temperature.

Key words: Goats; feed and water restrictions; digestibility coefficients

INTRODUCTION

The lack of available food (Doreau *et al*. 2003), relatively low quality forage (Silanikove 1986; Ahmed and El Shafei 2001) and limited water availability (Shkolnik and Silanikove 1981; Mengistu *et al*. 2007), are major factors influencing the productivity of ruminants in desert and tropical regions.

Grazing lands constitute the main feed resource for ruminants in most countries. In the Sudan, the most abundant sources of ruminant feeds are natural pastures, crop residues and agro-industrial by products. The concentration of livestock around water sources have created the present situation that where there is still some water there is no more forage, and where there is still forage there is no water (Qureshi 1986). Animals have to walk long distances in search for food and water and spend up to five days without water. The ability of a grazing animal to survive prolonged periods of water deprivation allows them to graze far from the watering site and to exploit the desert pasture evenly and efficiently (Nicholson 1987).

In many parts of the world, goats are preferred by animal producers due to better tolerance and performance under harsh environments, especially in predominantly semi-arid regions (Silanikove 2000). In Sudan, goats may be classified into four major types: Nubian goats, Desert goats, Nilotic goats and Tagger (Mason and Maule 1960).

There is a scarcity of information on Sudan Nubian goats when subjected to stress (water and feed restrictions). The present study was thus initiated with the objectives of investigating the effects of water and feed restrictions on the digestibility of nutrients, some rumen fermentation products, BUN concentration, rectal temperature and respiration rate in a manner, to some extent, similar to that encountered by goats during marketing and transport.

MATERIALS AND METHODS

General procedures

Three yearling uncastrated intact males of Sudan Nubian goats ranging in weight between 14 and 20 kg were used in this study. The animals were bought from the local market. On arrival at the experimental farm, they were treated with Levafas against endoparasites, sprayed with Gamatox for control of ectoparasites and given a prophylactic dose of Alamycine.

The animals were left to acclimatize for 14 days, during which they were allocated at random to each of the experimental treatments. Animals in group one [T_1] were given *adlibitum* feed and *adlibitum* water, in group two [T_2] were given feed restricted to 50% of the *adlibitum* intake and *adlibitum* water and in the third group [T_3] were given *adlibitum* feed and water restricted to 50% of the *adlibitum* water intake. Water was served in metal buckets tied securely on to the crates. The animals in T_1 and T_2 had free access to water, and water consumed by each goat was determined by measuring the depletion in the bucket and correcting for evaporation. During the experiment, the animals in T_1 and T_3 were provided with alfalfa (*Medicago sativa*) hay *adlibitum*. Prior to the experiment, fresh alfalfa was dried into hay and then chopped and thoroughly mixed before feeding. The chemical composition of alfalfa hay, on dry matter (DM) basis, was as follows: organic matter (OM), 11.8% crude protein (CP), 12.6% ether extract (EE), 1.9% crude fibre (CF) and 24% nitrogen-free extract (NFE), 49.7% metabolizable energy (ME) was calculated after MAFF (1975) using the following equation: ME (MJ/Kg DM) = 0.012CP+ 0.031EE+ 0.005CF+ 0.014NFE. It amounted to 10.3 MJ/Kg DM.

The study was conducted in early summer (May - June).The experimental conditions prevailing in the vicinity of the animals were recorded daily at 08.0 and 13.30 (Table 1). There were no marked fluctuations in the mean maximum and minimum air temperatures and relative humidity during the experimental period. The climatic data were obtained from Sudan Meteorology Authority.

Table 1. Climatic conditions in the vicinity of the animals during the experimental period

Date		Maxi-Tempe-rature (°C)	Mini-Tempe-rature (°C)	Relative Humi-dity(%)	Wind Velocity (km/h)	Evapor-ation (mm/day)	Sun shine (h/day)
May 2005	17*1	41.7	26.6	10	9	15	10.7
	18*1	41.7	28.5	10	8	16.3	11.0
	19*1	42.6	27	8	7	14.5	11.0
	20*1	43.2	26.5	8	5	15.0	11.2
	21*1	43.5	27	9	5	13.0	9.0
	31*2	42.0	30.0	30	4	11.0	6.4
June 2005	1*2	44.5	31.5	13	7	14.0	7.5
	2*2	45.1	31.8	15	11	13.0	10.6
	3*2	41.2	30.7	35	12	9.5	5.8
	4*2	41.5	29.5	33	10	11.0	8.6
	14*3	42.5	29.3	33	11	11.5	10.5
	15*3	43.0	31.0	27	10	14.0	9.2
	16*3	43.0	32.0	26	6	13.5	8.0
	17*3	43.7	30.5	30	6	11.0	9.8
	18*3	42.5	28.0	23	9	15.5	10.0

Source: Sudan Meteorology Authority, Khartoum

*1 Collection period No. 1

*2 Collection period No.2

*3 Collection period No.3

Digestion trial

The animals were harnessed and kept in metabolism cages to allow the collection of faeces and urine separately. After 14-day adjustment period, DMI was recorded for 7 days and dry matter digestibility (DMD) was measured during a 5 days collection period. The digestibility trial lasted for 45 days (3 collection periods). Each collection period (5 days each) was preceded by 10 days adjustment period.

Daily faecal excretions were collected in canvas bags. Ten percent of each goat's faecal output was dried daily at 105˚C for 24 hours for DM determinations, and the remaining quantity was bulked and refrigerated. At the end of the collection period, the composted faecal samples were mixed well, sub-sampled, dried at 60ºC for 24 hours, ground and used for chemical analysis.

Samples of feed offered were taken weekly and bulked at the end of the collection period. The collection composites were divided into two portions: one dried at 60 ºC and the other at 105 ºC for chemical analysis and DM determinations, respectively. The samples of feed and faeces were analyzed for their proximate chemical components as described by AOAC (1980). Digestion coefficients were calculated according to standard procedures (Schneider and Flatt 1975).

At the end of the digestibility trial, the goats were fasted for 24 hours, then they were offered their normal treatment. Samples of rumen liquor were obtained by means of a stomach tube immediately before feeding, 3h and 6h after feeding. The rumen liquor samples were strained through 4 layers of cheesecloth after they were centrifuged at 3000 rpm for 5 minutes and kept for immediate analysis. Rumen NH_3-N was determined as described by Conway (1957), and rumen pH was measured using Electronic pH Meter (Model 41600).

Blood samples were withdrawn from the jugular vein immediately before feeding, and three and six hours after feeding. The blood samples were allowed to clot, and the serum was separated by centrifugation and stored at -20ºC until assayed for blood urea (Conway 1957).

Rectal temperature was recorded with a telethermometer, and respiration rate by counting the flank movements. All the observations were recorded when the animals were in resting state under shade.

The data were analysed as 3 x 3 latin square design, using SPSS (1993). Data for ruminal metabolites and BUN, as affected by sampling time, were subjected to analysis of variance (SPSS 1993). Duncan's multiple range test was used for mean separation at $P \leq 0.05$.

RESULTS AND DISCUSSION

Chemical composition of the experimental feed

As indicated earlier, the percentage of CP in the alfalfa hay was low (12.6%). This may be attributed to one or more of the following factors:

- Low nitrogen content of the soil
- Using fresh alfalfa cut at the late stage of maturity (late bloom stage)
- Using hays that are mostly stems or have a lot of shattered leaves due to improper hay making, as the leaves contain most of the protein and nutrients that are highly digestible.

The Ohio State University Bulletin Extension (2001) reported that CP may vary about 2% based on soil fertility and hay making conditions.

Effects of feed and water restrictions on DMI, water intake, faecal DM, urine volume, rectal temperature and respiration rate in Sudan Nubian goats

The results (Table 2) revealed no treatment effects ($P>0.05$) on water intake, urine volume, rectal temperature and respiration rate. However, DMI differed significantly ($P<0.05$) between treatments. The DMI was 0.85, 0.46 and 0.80 kg in T_1, T_2 and T_3, respectively. The DMI was lower with T_2 (50% feed restriction) compared with T_3 (50% water restriction). English (1966) restricted the water intake of sheep to about 50% of adlibitum consumption and observed a decrease in DMI amounting to about 30% less than the drop in total water intake. Utley *et al.* (1970) reported that the feed intake is significantly correlated with water intake. They noticed that as water intake was reduced to 60% of free choice, the feed intake was significantly ($P<0.05$) decreased from 6.2 kg to 4.8 kg per day. Ahmed and Elshafei (2001) found that the DMI was affected neither by feed restriction nor by water restriction in desert goats fed high or low quality roughages.

The *adlibitum* provision of water (Table 2) resulted in insignificantly higher water intake compared with the other two treatments. This is in line with the findings of Hadjigeorgiou *et al*. (2000) and Ahmed and Elshafei (2001) who reported a non-significant decreasing trend of water intake as a result of water restriction.

Faecal DM and urine output were highly correlated with water intake. Reducing the water intake resulted in significant ($P<0.05$) reduction in faecal water excretion when water was restricted to 50% of free choice. Similar findings were reported by Utley *et al*. (1970). Restriction of water resulted in insignificant reduction in urine volume. This is in line with the findings of Utley *et al*. (1970) who reported a significant reduction in urine *volume* as a result of water restriction. Schmidt-Nielsen (1964) stated that water restriction decreased total urine output and enhanced urea recycling to the forestomach. This is evidenced by the high plasma urea concentration (Table 2).

The effects of water restriction are felt in areas of energy production and thermoregulation (King 1983). In terms of energy production, water restriction reduces DM consumption and hence endogenous heat production and so reduces the water requirement for evaporative cooling. The decrease in metabolic heat production was indicated by the decrease in rectal temperature (Table 2). Macfarlane and Howard (1972) stated that evaporative cooling would allow water economy. Ahmed and Abdelatif (1994) stated that the decrease in urine output, faecal water output and water turnover rates show how reduced food intake serves to conserve water during periods of drought.

Rectal temperature decreased ($P>0.05$) due to feed restriction, but the decrease was insignificant. Similar findings were reported by Ahmed and El Kheir (2004). However, the difference between treatments was significant ($P<0.05$). Rectal temperature was higher in water restricted goats than in feed restricted goats, whereas respiration rate decreased

(P>0.05) with both feed and water restriction. This confirms the findings of the above mentioned researchers.
Daily measurements of rectal temperature and respiration rate suggested that the health of the animals was not affected by treatment.

Table 2. Effects of feed and water restriction on DMI, water intake, faecal DM, urine volume, rectal temperature and respiration rate in Sudan Nubian goats

Parameter	T_1 Mean ± SD	T_2 Mean ± SD	T_3 Mean ± SD
DMI (kg/day)	0.85 ± 0.05^a	0.46 ± 0.04^b	0.80 ± 0.10^c
Water intake (ml/day)	2948.0 ±880.29	2565.33±241.92	1669.33±334.24
Water intake /DMI (litre/kg)	3.64 ± 1.08	5.91 ± 0.18^b	2.22 ± 0.59^c
Faecal DM (g/day)	185.17 ± 37.89^a	118.75 ± 13.10^b	162.79 ± 19.59^c
Urine volume (ml/day)	803.89±86.36	534.67±14.50	345.0±145.32
Rectal Temperature (°C)	38.70 ± 0.29	38.25±0.30	38.60±0.35
Respiration rate (Breathes/min)	18.67 ± 6.66	15.33 ± 1.76	17.22 ± 5.42

Values are means ± SD of three animals.
Values in the same row with different superscripts differ significantly (P<0.05).
T_1: *Adlib*. feed and water
T_2: 50% feed, *adlib*. water
T_3: *Adlib*. feed, 50% water

Apparent digestibility coefficients of the proximate components and TDN as affected by water and feed restrictions

The effects of feed and water restrictions on the apparent digestibility coefficients in Sudan Nubian goats are shown in Table 3. The results revealed that feed and water restrictions had no significant effects on the digestibility coefficients of the various proximate components. In line with the data of Hadjigeorgiou *et al*. (2000), restriction of water intake did not have any significant effects on the digestibility of the proximate components. Brun-Bellut *et al*. (1988) stated that imposing a reduction of up to 40% in voluntary feed intake of a forage diet at near maintenance was associated with no appreciable effect on the digestibility. This is in accord with the present results.

There was no reduction in the overall apparent digestibility of the proximate constituents in addition to the TDN in the feed restricted goats compared with the control group (*adlibitum* feed, *adlibitum* water). The water restricted goats showed different trends except for EED which decreased compared with the control group. Osman and Fadlalla (1974) reported that the mean digestibility coefficients of OM, CP and NFE were slightly improved by water restriction, while the EED was significantly ($P<0.05$) reduced by water restriction. In this study, the decrease in EED was insignificant. The decrease in CFD reported by Osman and Fadlalla (1974) was not in accord with the findings obtained in this study.

Ghosh *et al*. (1983) stated that the increased digestibility with reduced free drinking water may possibly be explained in terms of decreased rate of passage of ingesta in the alimentary tract. Bohra and Ghosh (1983) postulated that the improvement in the efficiency of digestion in water restricted sheep may not be due to an enhanced microbial activity in the rumen, but may be possibly due to an increased absorption of feed nutrients in the hind gut of these animals. The results obtained in this study (Table 2) revealed that DMI decreased by treatment. It is difficult to determine if the trend towards increased apparent digestibility coefficients was due to reduced water intake or reduced feed intake since both factors occurred simultaneously. The treatment had no significant effect on the TDN values. Similar results were obtained by Ahmed and Abdelatif (1994). TDN tended to be higher with water restriction. This confirms the data obtained by the above mentioned researchers. However, Ahmed and Elshafei (2001) reported that TDN was significantly affected by both water and feed restriction in desert goats fed lucerne hay. However, the TDN values obtained in their study were lower than those found in this study.

Table 3. Effects of feed and water restriction on the apparent digestibility coefficients (%) and TDN in Sudan Nubian goats

Parameter	T_1 Mean ± SD	T_2 Mean ± SD	T_3 Mean ± SD
Dry matter	76.93 ± 5.91	72.69 ± 1.30	78.34 ± 4.62
Organic matter	77.76 ± 5.78	73.88 ± 1.46	79.55 ± 4.49
Crude protein	79.52 ± 5.84	75.47 ± 2.48	80.15 ± 6.00
Ether extract	51.71 ± 11.35	43.98 ± 6.26	47.38 ± 16.98
Crude fibre	74.96 ± 6.15	70.67 ± 1.02	76.90 ± 5.38
Nitrogen free extract	79.68 ± 5.69	76.22 ± 2.87	81.90 ± 3.52
Total digestible nutrients (%)	69.85 ± 5.35	66.26 ± 1.29	71.31 ± 4.40

Values are means ± SD of three animals.
Values in the same row with no superscripts are not significantly different (P>0.05).
T_1: *Adlib*. feed and water
T_2: 50% feed, *adlib*. water
T_3: *Adlib*. feed, 50% water

Effects of feed and water restrictions on some rumen fermentation parameters and BUN

The data of some rumen fermentation parameters and BUN, as affected by feed and water restrictions, are shown in Table 4. There was no significant treatment effect on rumen pH, NH_3-N and BUN. Rumen pH was not affected by treatment. This is in contrast to the findings of Ahmed and Abdelatif (1994) who reported that water restriction significantly decreased the pH. They attributed this reduction to reduction in rumen volume and reduced salivary secretion and the increase in the concentration of volatile fatty acids (VFA). Patnayak and Leffel (1969) found that rumen pH did not differ significantly due to level of intake. This contradicts the findings of Hermesmeyer *et al*. (2002) who found that the rumen pH was lower for steers which had *adlibitum* access to finishing diet compared with a diet restricted to 75% of predicted *adlibitum* intake.

Generally, the rumen pH tended to decrease three hours after feeding compared with the fasting or six hours after feeding. Similar trend was reported by Rumsey *et al*. (1970). Some investigators found that when the level of intake decreases, pH in goats and sheep rumen fluid generally moderately increases (Zhao *et al*. 1993; Ahmed and Abdelatif 1994; Kabrè *et al*. 1994) or remains constant (Djajanegara and Doyle 1989), whereas VFA decreases these two phenomena being related. Ahmed and Abdelatif (1994) attributed the increase in pH with food restriction to the high ratio of water intake to DMI and dilution of VFA concentration as well as a decline in VFA production.

Rumen NH_3-N concentrations (Table 4) were not affected by treatment. Different results were reported by Ahmed and Abdelatif (1994) who found that with feed restriction, the rumen NH_3-N concentration increased significantly three hours after feeding, whereas the concentration of NH_3-N in the water restricted desert rams was not significantly different from the desert rams given *adlibitum* water and feed. The previous findings are in line with the results obtained by Toha *et al*. (1987) who found that rumen NH_3-N concentrations are not affected significantly ($P>0.05$) by the level of water intake.

The NH_3-N concentration tended to increase three hours after feeding compared with the fasting or six hours after feeding. The NH_3-N concentration was higher than the rumen NH_3-N concentration of 5 mg/100ml reported by *Satter* and Slyter (1974) as being necessary for maximal protein synthesis. Owens and Bergen (1983) reported that concentrations ranging from 3.5 to 29 mg/100 ml promote maximal microbial growth.

Blood urea-N (BUN) concentrations (Table 4) were not significantly affected ($P>0.05$) by treatment. These results are in line with the findings of Kannan *et al.* (2007) in goats subjected to feed and water restrictions. However, the results of Ahmed and Abdelatif (1994) showed that plasma urea-N (PUN) concentration increased significantly ($P<0.01$) only with water restriction in adult desert sheep when used to evaluate the effects of water restriction (46% *adlibitum* level) and feed restriction (32% *adlibitum* level). On the other hand, Cole and Hutcheson (1987) reported that PUN increased significantly ($P<0.05$) as a result of feed and water deprivation. The lower BUN values in previously fasted lambs suggests that the fasted lambs were using N more efficiently than continuously fed lambs (Cole *et al*. 1988) or had a lower absorption of N from the gut.

In conclusion, feed and water restrictions had no significant effects on most of the parameters investigated (water intake, urine volume, rectal temperature, respiration rate, digestibility coefficients of the proximate components, TDN, rumen pH and rumen NH_3-N). This may be an indication that Sudan Nubian goats are well adapted to the harsh environment in Sudan. However, more research is needed to investigate the effects of water and feed restrictions on production responses using larger number of animals.

Table 4. Effects of feed and water restriction on rumen pH, NH_3-N and BUN in Sudan Nubian goats

Parameter	T_1 Mean ± SD	T_2 Mean ± SD	T_3 Mean ± SD
pH			
Before feeding	7.66 ± 0.12	7.59 ± 0.11	7.64 ± 0.08
3hrs after feeding	6.91 ± 0.09	7.10 ± 0.21	7.04 ± 0.19
6hrs after feeding	7.35 ± 0.46	6.94 ± 0.28	7.31 ± 0.20
NH_3-N (mg/100ml rumen liquor)			
Before feeding	11.53 ± 1.43	12.27 ± 1.37	14.89 ± 5.48
3hrs after feeding	21.42 ± 3.50	21.75 ± 3.11	23.24 ± 6.12
6hrs after feeding	17.45 ± 4.98	15.68 ± 2.46	15.77 ± 8.42
BUN (mg/100ml blood)			
Before feeding	31.66 ± 2.45	24.03 ± 5.00	32.20 ± 7.70
3hrs after feeding	40.94 ± 5.62	33.13 ± 5.75	44.37 ± 16.51
6hrs after feeding	39.58 ± 9.62	37.93 ± 5.40	36.95 ± 7.52

Values are means ± SD of three animals.
Values in the same row with no superscripts are not significantly different (P>0.05).
T_1: *Adlib*.feed and water
T_2: 50% feed, *adlib*. Water
T_3: *Adlib*.feed, 50% water

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معاملات الهضم الظاهري وبعض نواتج التمثيل الثانوية للدم والكرش والاستجابات الفسيولوجيه في الماعز النوبي السوداني عند تعرضه لمستويات مختلفه من نقص العلف والماء

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المستخلص: إستخدمت ثلاثة ذكور من الماعز النوبى السودانى، الغير مخصى والبالغة من العمر سنة و وزنها بين 14و20 كجم، فى تصميم 3 3x مربع لاتينى بهدف دراسة تأثيرات تقليل العلف والماء على المادة الجافة المأكولة، وماء الشرب المستهلك، ومعامل هضم العناصر الغذائية، ومكونات سائل الكرش، ويوريا الدم، ودرجة حرارة المستقيم، ومعدل التنفس. إحتوت التجربة ثلاث معاملات: تقديم علف حتى الشبع وكذلك الماء، وتقليل العلف إلى 50% من مستوى الشبع، وتقليل الماء إلى 50% من مستوى الشبع. أوضحت النتائج عدم وجود تأثير معنوي للمعاملة على ماء الشرب المستهلك، وحجم البول، ودرجة حرارة المستقيم، ومعدل التنفس. من ناحية ثانية، اختلفت كمية المادة الجافة المأكولة معنوياً بين المعاملات. لوحظ أن تقديم الماء حتى الشبع نتج عنه زيادة غير معنوية فى ماء الشرب المستهلك مقارنة بالمعاملات الأخرى، وأن درجة حرارة المستقيم كانت أعلى فى الماعز الذى تعرض لتقليل الماء مقارنة بالماعز الذى تعرض لتقليل العلف. كما نقص معدل التنفس نقصاً غير معنوي فى كل من حالتى تقليل استهلاك العلف والماء. تقليل استهلاك العلف والماء لم يكن له تأثير معنوي على معامل هضم العناصر الغذائية المختلفة. لم يلاحظ أى إنخفاض فى معامل هضم العناصر الغذائية وكذلك فى المواد الغذائية الكلية المهضومة فى الماعز الذى تعرض لتقليل استهلاك العلف. أظهر الماعز الذى تعرض لتقليل استهلاك الماء نمطاً مختلفاً فيما عدا معامل هضم مستخلص الأيثر والذى مال للنقصان. لم يكن للمعاملة تأثير معنوي على قيم المواد الغذائية الكلية المهضومة. كان هنالك ميلاً لزيادة المواد الغذائية الكلية المهضومة بتقليل استهلاك الماء، ولم يكن هنالك تأثير معنوي للمعاملة على درجة تركيز أيون الهيدروجين (pH)

فى الكرش، والأمونيا، ويوريا الدم. لم يؤثر نقص الغذاء والماء معنويا علي معامل الهضم والعناصر الغذائية لكن كان هنالك ميلاً للتأثير بصورة طفيفة علي نواتج التمثيل الثانوية في الكرش ويوريا الدم ومعدل التنفس ودرجة حرارة المستقيم.