FORAGE PREFERENCE OF BOER GOATS IN THE HIGHLAND SAVANNA DURING THE RAINY SEASON

II: NUTRITIVE VALUE OF THE DIET

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ABSTRACT

The diet selected by pregnant Boer goat does in *Acacia*-dominated highland savanna during the rainy season was compared to the nutritive value of randomly collected forage from the same forage species, and to the nutrient requirements of goats. Only woody forage species were sampled, either randomly or in a manner imitating the selectivity observed in goats, by hand-plucking. All samples were analysed for their nutritive value and digestibility.

Goats managed to select a diet from browse that contained more of the major nutrients (except fat) and was more digestible and juicier than the randomly sampled browse on offer in the feeding area. However, when compared to their nutrient requirement, does appeared to be marginally deficient in energy intake, while dietary protein was somewhat and dietary calcium grossly oversupplied.

The need for extra dietary energy may force pregnant and lactating goats to select more herbaceous material than expected, as observed during diet selection trials, because herbaceous plants contain relatively more energy-equivalents than browse. Some of the excess dietary protein is made indigestible by binding to tannin, which is common in the browsed forage of arid savannas. Excessive dietary calcium may be a boost to lactating does, but may also induce a deficiency in some other minerals. From a nutritional perspective, it is recommended that goat does be supplemented with energy and minerals, other than calcium, during their lactation. However, the financial feasibility of such a practice will have to be evaluated.

INTRODUCTION

Diet selection is the ability of an animal to select from the available foods in its environment those that can satisfy its nutritional requirements (Rogers and Blundell, 1991). The amount of food ingested voluntarily is probably the first obstacle encountered by a free-ranging animal in a nutritionally challenging environment such as Namibia's arid rangelands, since sufficient food may not be available at all times of the year. However, once sufficient food has been ingested, it is the quality of that food which determines the productivity of an animal. The selectivity expressed by an animal during foraging is a major determinant of the quality of the ingested food, although the opposite is also true: foods of higher quality are more frequently selected than those of low quality.

The nutrient requirements of meat-type goats have been quantified in detail (for example, NRC, 1981), using mostly constrained and stall-fed animals. The choices facing a free-ranging animal, confronted with an extremely heterogeneous environment from which to select food, are many more than those facing an animal on pasture, or stall-fed. It is therefore much more difficult to determine the quality of ingested food in free-ranging than in constrained animals (Forbes, 1995). However, since animals are what they eat, it is crucially important to know to what extent an animal succeeded in selecting foods that meet its nutritional requirements. There is no published information on the nutritive value of diets selected by Boer goats in Namibia, although the chemical composition of some of their principal forage species is known. However, goats do not select forage at random, but are very specific, picking certain plant organs or parts and leaving others. It is therefore quite likely that goats may select a diet that differs from the chemical composition of forage species sampled without prior knowledge of which organs would have been selected by goats (Devendra and McLeroy, 1988; Peacock, 1996). Since the aim of part I of this article was to establish the diet selection of Boer goats, it presented an opportunity to evaluate the nutritive value of the selected diet as well.

The variety of methods available to investigate the quality of the selected diet indicates the importance of this aspect of livestock production (Nogueira, 1993). Many investigators believe that diet quality can only be determined accurately on samples obtained directly from ingested food (Weir et al., 1959), preferably using esophageal fistulas or natural or artificial markers. However, these techniques are not without their problems. For example, the chemical analysis of esophageally-collected ingesta is fraught with inaccuracies related to saliva contamination, addition of endogenous nitrogen to the ingesta and sample preservation (Scales et al., 1974; Nogueira, 1993), in addition to the veterinary and ethical difficulties of fistulating animals. In contrast, hand-plucking of samples following an observed pattern of diet selection by animals, is at best a simulation of what an animal has really ingested. Given that hand-plucking is easy, cheap and practical, it is in widespread use world-wide despite its inherent inaccuracy (Weir and Torell, 1959; Holechek et al., 1982; Nogueira, 1993). The problem of accurately determining the extent to which an animal selected a diet, containing sufficient nutrients for its requirements, can be partly overcome by comparing a simulated sample, imitating animal diet selection, to a standard sample. This standard should be a randomly picked sample, picked as though no prior knowledge of animal diet selectivity existed (Nogueira, 1993). This recommendation was followed in part II of this trial: those organs or parts of forage plants seen to have been utilised by goats during observation of their diet selection, were hand-plucked and compared to randomly collected samples of the same forage plants, despite the obvious drawback of imitating, rather than duplicating, goats' diet selection.

MATERIALS AND METHODS

Samples of all woody species utilised by the three marked Boer goat does described in part I of this article were collected towards the end of the trial, once it had become clear which plants and plant organs were utilised. This occurred in March 1999, after 92% of the season's rain had already fallen and woody plants were growing well. Non-woody forage species were not sampled, mainly because grasses, herbs and forbs utilised were not identified at species level, as they were not expected to contribute much to the diet of goats.

Two different samples were collected by hand-plucking from each of the 13 woody species utilised by goats: a "random" sample and an "imitated" sample. The random sample was collected by cutting off complete terminal branches thinner than 5 mm in diameter, containing the organs: terminal branch-end (< 5 mm in diameter) with shoot, leaves, thorns or spikes and flowers, if present. Seeds and pods were not included. Imitated samples were collected in a manner which attempted to imitate the browsing selectivity observed in goats during bite-counting, and consisted predominantly of leaves, often with the actively growing shoot (terminal bud) or some flowers included. Since it is possible that individual plants within a species differ in their nutrient content, which can also be affected by their location, each sample was collected from at least five different individual plants, growing far apart. All samples were immediately sealed in plastic bags *in situ*, to prevent moisture loss.

The 26 samples were then dried in an oven at 60°C for 5 days to determine their natural dry matter content. After this, they were subjected to standard analytical procedures to establish their content of crude protein (% CP) (methods 4.2.02 and 32.2.03 of AOAC, 1995), crude fibre (% CF) (method 4.6.01 of AOAC, 1995), acid detergent fibre (% ADF) (Goering and Van Soest, 1970), neutral detergent fibre (% NDF) (Robertson and Van Soest, 1981), digestibility of the organic matter (% DOM) (Menke et al., 1979), metabolizable energy (MJ ME/kg) (Menke et al., 1979), crude fat (%) (method 4.5.01 of AOAC, 1995), total ash (%) (method 4.1.10 of AOAC, 1995), calcium (% Ca) (Price, 1972) and phosphorus (% P) (Cavell, 1955).

Statistical analysis of the data was performed by treating the nutrient content of goat-imitated and randomly selected samples as a paired comparison design. Matched pairing of samples is justified when samples are related (goat-imitated and random samples come from the same forage species), but can be expected to differ from each other (due to different picking procedures) and are not replicated (mainly due to the expense of chemical analysis) (Montgomery, 1991). The difference in a nutrient between the two sample blocks across all 13 forage species ($\mu_{\text{goat-imitated sample } i} - \mu_{\text{random sample } i}$ for each individual nutrient and forage species) served as replication, which was subjected to a one-sided, paired-sample t-test, as it could reasonably be expected that goats would select a more nutritious diet from the available vegetation than random sampling would achieve (Stephens and Krebs, 1986; Forbes, 1995). Nonetheless, the null hypothesis (H_0) stated that imitated samples do not differ from random samples in their nutritive value. Differences in nutrient content between various forage species were tested using a standard F-test. All tests were performed at an á level of 0.05, using the SPSS, version 10.0, computer package (Bryman and Cramer, 1997) as analytical tool.

RESULTS AND DISCUSSION

The nutritive value of forage plants, sampled at random, is presented in Table 1, while the nutritive value of the same forage species, sampled in a manner imitating selection by Boer goats, is presented in Table 2. Only in the case of *Hermannia modesta* was it unnecessary to sample the plant differently, since goats utilised all above-ground organs of this soft, shrubby plant. Differences in nutritive value between individual forage species are highly significant ($P<0.01$), irrespective of the sampling method used. There is no obvious pattern to the nutritive value of forage plants, e.g. that spinescent plants have a higher or lower content of a certain nutrient than non-spinescent plants. Harvesting only branch tips less than 5 mm in diameter for random samples is justified by the diameter - mass relationship established by Mapuma et al., (1996).

Differences in the nutritive value between samples collected in a manner imitating Boer goat selection and samples collected at random from the same forage species, are illustrated in Figure 1. Analysis of matched pairs (with df = 12) indicated that all differences between goat-imitated and random samples were significant ($P<0.05$), except for the calcium, phosphorus and fat content of samples, which did not differ significantly between sample types. As argued by Nogueira (1993), in the absence of a totally satisfactory technique to determine diet quality in free-ranging animals, a comparative presentation can clarify whether an animal succeeded in selecting sufficient nutrients from the available vegetation, or not. In general, the nutritive value of goat-imitated samples coincides roughly with values reported in the literature (Narjisse, 1991; Webber et al., 1996), which apply mainly to temperate forages, indicating a dearth of published information on the quality of diets selected by goats in tropical parts of the world (Devendra and McLeroy, 1988; Peacock, 1996). Similar differences in the nutritive value of samples collected by goats or randomly were observed by Els (2000), who used esophageal fistulae to determine the nutritive value of all ingested forage, including herbaceous material.

From the results presented in Figure 1, it can be inferred that goats selected forage components which consistently contained more nutrients than randomly-sampled vegetation in the feeding area (as indicated by higher protein, calcium, phosphorus, ash and metabolizable energy content of goat-

Dietary protein was in oversupply by a factor of 2.36 compared to requirement. However, some of that dietary protein would have been made unavailable to the animal's digestive processes by binding with tannin, an anti-nutrient commonly found in tropical trees and shrubs (Peacock, 1996). In *Acacia karroo*, tannin levels increase after browsing and discourage continued browsing. It was found that the intake of leaves and shoots was negatively related to tannin content, but positively related to digestibility, influencing the pattern of selection for different plant parts by goats (Teague, 1989). After binding to tannins, any remaining excess dietary protein can be converted into energy by certain metabolic pathways in the body, albeit inefficiently. It is quite common that, in browsers, dietary crude protein concentrations exceed animal requirements (Stuth and Kamau, 1990).

It appears that the goats' requirements of the major minerals, calcium and phosphorus, were well met. Calcium is actually oversupplied by a factor of 7.13 compared to requirement. However, the NRC (1981) requirements are for does in early pregnancy and since lactating does require an additional 3g of dietary calcium for every 1 kg of milk produced (NRC, 1981), an apparent oversupply of calcium before kidding could easily turn into "just enough" in early lactation, when Boer goats are known to yield as much as 2 kg of milk/day (Devendra and McLeroy, 1988).

Some of this excess calcium may derive from soil-contamination of goat-imitated samples. However, excess dietary calcium may become problematic once the doe stops lactating, as it may induce a deficiency in another mineral, especially magnesium, copper or zinc, and may interfere with the absorption of phosphorus (Underwood, 1981). Most of these minerals have been reported to be of marginal status in Namibia, primarily due to high soil and dietary calcium levels (Boyazoglu, 1976; Grant et al., 1996).

Goats in this trial were stocked at a moderate rate. As stocking rate increases, the relative proportion of forage species selected by goats changes, due to increasing competition between individual animals. Increasing the stocking rate affects intake of nutrients (Mbuti et al., 1996) by decreasing digestibility (Lu, 1988) and probably by decreasing the total amount of nutrients ingested to the detriment of animal productivity. Similar effects have been observed due to change in season (Raats et al., 1996; Rothauge and Engelbrecht, 2000).

The average nutrient content of organs of woody forage plants selected by goats, as presented in Table 2, is of course only an arithmetic average, not weighted according to the relative abundance of these forage species in the goat's diet. In part I of this trial, it was determined that the three woody species *Phaeoptilum spinosum, Acacia mellifera* and *Catophractes alexandri* alone, constitute nearly one-third of the goat's diet. These three principal forage species are fairly average in their nutritive value and it can therefore not be expected that they alleviate any deficiency or excess in the total diet. However, it may be possible that the lactating doe can improve her apparently insufficient energy intake by selecting a considerable proportion of herbaceous material in summer, in addition to the principal browse species. Herbaceous, non-woody forage plants contributed nearly as much to the total diet of goats as all woody forage species together (part I of this trial) and contain more energy-equivalents, albeit less protein, at the peak of the vegetative growing season than browse material (Meissner et al., 1999). The reason for goats' increased intake of grasses, herbs and forbs in summer may thus be not only the increased palatability of these highly seasonal plants, but also the lactating doe's inability to meet her energy requirements from the principal diet component, browse, alone. In winter, during the vegetative dormant season, herbaceous plants are much less nutritious and palatable than in summer (Meissner et al., 1999) and the doe is not in milk anymore, reducing the need of the doe to consume a large proportion of herbaceous plants, as was indeed observed in a trial similar to this one, but held in winter (Rothauge and Engelbrecht, 2000).

CONCLUSION

Even though hand-plucking is not an ideal method to determine dietary quality of free-ranging animals, it appears that Boer goat does in late pregnancy or early lactation are quite able to meet their increased nutritional requirements from the natural vegetation on offer in Namibia's highland savanna during the rainy season in summer. The energy content of the principal diet component, browse, may be marginally insufficient, forcing the doe to ingest an increased proportion of herbaceous plants to meet her temporarily increased energy requirement. The intake of other major nutrients meets or exceeds requirement and calcium in particular appears to be hugely oversupplied by forage. A high calcium intake may be beneficial to lactating does, but may induce mineral deficiencies in non-lactating does. If it is expected that minerals which are sensitive to high dietary calcium levels are in short supply in a certain area, it may be worthwhile to supplement these by way of mineral licks or ruminal insertion of metal or glass capsules. Lick supplementation is a convenient way to alleviate any potential energy deficiency too, reducing weight and condition loss in lactating does and facilitating re-conception. However, whether the expected increase in the performance of supplemented animals would actually compensate for the cost of supplementing energy and minerals to free-ranging does in summer, would have to be determined by further trials. In principal, a cost-effective response can only be expected when goats are stocked at high density.

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Table 1. The nutritive value of woody forage plants utilized by goats, but sampled at random

WOODY FORAGE SPECIES	DM %	CP %	CF %	ADF %	NDF %	DOM %	ME MJ/kg	Fat %	Ash %	Ca %	P %
Acacia hebeclada	65.3	15.83	21.96	39.19	48.38	47.2	6.0	1.99	9.86	1.55	0.16
Acacia hereroensis	62.2	10.60	28.28	48.33	58.79	39.0	5.3	1.33	5.15	1.46	0.17
Acacia karroo	58.9	16.25	33.08	55.98	65.44	39.5	5.3	0.61	4.91	1.81	0.18
Acacia mellifera	53.6	8.10	41.47	52.93	64.32	40.3	5.6	1.68	4.32	1.31	0.11
Catophractes alexandri	55.3	11.23	37.35	51.24	56.89	49.2	6.5	1.11	7.63	1.62	0.14
Grewia flava	55.9	14.83	39.43	45.91	59.43	34.2	4.6	1.05	7.57	1.52	0.20
Hermannia modesta	45.0	17.36	26.94	33.10	48.08	58.7	7.1	0.89	15.14	2.27	0.14
Leucosphaera bainesii	55.5	17.22	21.19	34.62	43.18	61.2	7.4	2.66	8.18	2.59	0.19
Lycium trothae	17.7	23.57	25.15	41.55	47.48	55.5	7.2	3.65	8.31	3.25	0.38
Phaeoptilum spinosum	50.6	10.07	33.56	47.67	60.87	46.6	5.6	1.86	7.65	1.35	0.14
Rhus marlothii	51.3	15.07	36.01	46.16	57.75	46.9	6.1	1.91	5.73	1.61	0.13
Tarchonanthus camphoratus	40.7	13.99	27.52	43.45	56.01	46.7	6.2	3.65	9.07	2.47	0.23
Ziziphus mucronata	43.3	15.13	24.09	32.33	41.55	57.0	8.1	2.32	4.27	1.11	0.19
Average	**50.4**	**14.56**	**30.46**	**44.04**	**54.47**	**47.8**	**6.2**	**1.90**	**7.52**	**1.84**	**0.18**
Standard deviation	**12.14**	**3.981**	**6.765**	**7.575**	**7.862**	**8.34**	**1.00**	**0.970**	**2.936**	**0.620**	**0.068**

Table 2. The nutritive value of woody forage plants utilized by goats, sampled in a manner imitating their selection of specific plant parts and organs

WOODY FORAGE SPECIES	DM %	CP %	CF %	ADF %	NDF %	DOM %	ME MJ/kg	Fat %	Ash %	Ca %	P %
Acacia hebeclada	57.9	16.43	20.79	30.21	38.08	68.8	7.7	2.82	16.67	1.56	0.17
Acacia hereroensis	57.0	14.74	29.08	43.65	51.47	46.6	6.1	2.03	7.88	2.27	0.17
Acacia karroo	38.8	17.31	27.71	41.02	50.99	44.8	6.0	2.44	6.98	1.94	0.19
Acacia mellifera	51.9	12.27	30.20	41.63	55.18	49.1	6.6	1.13	6.72	2.49	0.14
Catophractes alexandri	50.0	12.91	28.16	39.86	47.64	53.0	7.7	1.68	7.99	1.25	0.16
Grewia flava	51.7	16.07	28.07	48.90	59.92	44.3	5.8	2.02	5.08	1.44	0.15
Hermannia modesta	45.0	17.36	26.94	33.10	48.08	58.7	7.1	0.89	15.14	2.27	0.14
Leucosphaera bainesii	26.6	22.37	14.02	23.98	43.83	59.4	8.1	2.60	15.28	3.45	0.26
Lycium trothae	13.2	35.76	20.55	34.53	42.33	61.2	7.1	1.78	18.62	2.32	0.37
Phaeoptilum spinosum	44.0	13.65	26.17	40.01	54.86	47.6	6.3	1.54	13.54	2.46	0.13
Rhus marlothii	46.9	19.16	33.53	37.47	51.73	51.3	6.4	0.93	13.51	1.80	0.16
Tarchonanthus camphoratus	36.8	14.48	24.06	42.81	54.58	50.7	7.0	2.36	8.16	2.46	0.20
Ziziphus mucronata	35.5	20.72	10.88	16.99	35.60	64.3	8.9	1.09	6.96	2.96	0.19
Average	**42.7**	**17.94**	**24.63**	**36.47**	**48.79**	**53.8**	**7.0**	**1.79**	**10.96**	**2.21**	**0.19**
Standard deviation	**12.61**	**6.130**	**6.486**	**8.700**	**7.145**	**7.88**	**0.92**	**0.653**	**4.575**	**0.612**	**0.065**

imitated compared to random samples) and were more digestible (higher digestibility and lower crude fibre and fibre fractions content) and more juicy (lower dry matter content). Only in the case of crude fat, an energy substrate for animals, did goats not manage to select a diet with a higher content than was on offer (P>0.05). However, the chemical analysis of crude fat includes not only energy-supplying true fats and oils, but also substances like waxes, sterols and aromatic oils. These impart an unpalatable smell or taste to forage, which goats might therefore actually want to avoid rather than select preferentially (Peacock 1996), though it is also known that goats are quite tolerant to bitterness in weeds (Lu 1988).

Ash values determined in a laboratory represent the total mineral content of a feed, and were very high in goat-imitated samples (Table 2) compared to random samples (Table 1)

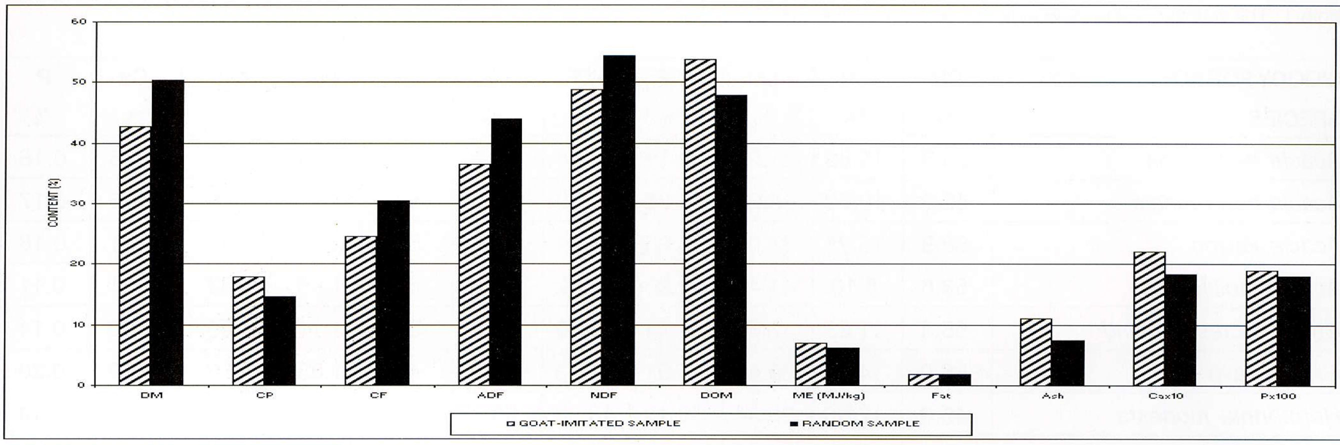

Figure 1. Difference in the nutritive value of goat-imitated and randomly selected samples.

(P>0.05). This difference has to be interpreted with caution, as many goat-imitated samples were contaminated with rain-induced soil-splash typical of samples collected fairly close to ground level. However, the higher calcium and phosphorus content of goat-imitated samples seems to indicate that goats managed to select a diet of higher mineral content than was on offer. In general, given the inaccuracies of hand-plucking, it can be assumed that goats would have selected an even more nutritious diet than indicated by goat-imitated samples. The null hypothesis, that there would be no difference in the nutritive value of random and goat-imitated samples, can therefore be rejected.

The nutrient requirements of goats are presented in Table 3, re-calculated from the NRC (1981) for goats of 57kg average live mass. Two levels of nutrient requirements are used: for goats at maintenance and for goats at 1.75 times maintenance. According to the NRC (1981), this maintenance increment is needed for does in early pregnancy and foraging on sparse vegetation in mountainous, arid rangeland. These circumstances were mirrored during the current trial, except that does were in late pregnancy, when nutritional requirements are even higher than during early pregnancy. The dry matter intake of free-ranging animals is notoriously difficult to determine. The NRC (1981) assumes that the dry matter consumed daily by goats at maintenance approaches 1.8% of their live mass and 3.2% at the higher level of production. Devendra & McLeroy (1988) caution that goats in the tropics seldom achieve an intake exceeding 3% of their live mass.

To compare the laboratory analysis of forage species, given in percent (Table 2), to nutrient requirements stated in absolute amounts by the NRC (1981), it was necessary to convert absolute into relative requirements, by dividing by the daily dry matter intake (Table 3). Now, nutritive content of forage plants (Table 2) is directly comparable to the required nutrient concentration in goats' diet (Table 3), with the exception of the digestibility of the organic matter (DOM, Table 2), which can only be equated roughly with the total digestible nutrients (TDN, Table 3).

Comparing the nutritive value of goat-imitated samples (Table 2) to the required dietary nutrient concentration (Table 3), it appears that the energy intake of does in late pregnancy and early lactation was insufficient to meet their requirements. Metabolizable energy concentration in selected forage was 16.1% less and digestibility was 2.7% less than required. However, does are able to buffer such short-term deficiencies in dietary energy quite well by mobilising body fat (Mackenzie, 1993), leading to a temporary drop in live mass and loss of body condition. Unfortunately, the goats in this trial were not weighed often enough to confirm this statement.

Table 3: The absolute (NRC 1981) and relative (re-calculated from NRC, 1981) nutrient requirements of meat-type goats at maintenance and at maintenance plus a 75% increment

NUTRIENT	REQUIREMENT:	ABSOLUTE *	REQUIREMENT:	RELATIVE **
	Maintenance	1.75 x Maintenance	Maintenance	1.75 x Maintenance
Dry matter intake	1050 g/d	1850 g/d	100%	100%
Total digestible	585 g/d	1023 g/d	55.7%	55.3%
Metabolisable energy	8.84 MJ	15.42 MJ	8.42 MJ/kg	8.34 MJ/kg
Crude protein	83 g/d	141 g/d	7.9%	7.6%
Calcium	3.0 g/d	5.7 g/d	0.29%	0.31%
Phosphorus	2.1 g/d	4.0 g/d	0.20%	0.22%

*: Re-calculated from NRC (1981) to fit goats of 57kg average live mass.

**: "Relative requirement" = absolute requirement relative to dry matter intake.