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Farid M.F.A., Khamis H.S., Abou El-Nasr H.M., Ahmed M.H., Shawket S.M.

in

Lindberg J.E. (ed.), Gonda H.L. (ed.), Ledin I. (ed.).
Recent advances in small ruminant nutrition

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 34

1997
pages 109-114

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M.F.A. Farid, H.S. Khamis, H.M. Abou El-Nasr, M.H. Ahmed and S.M. Shawket
Desert Research Centre, Al-Matareya, Cairo, Egypt

SUMMARY - Four female camels, sheep and goats were individually fed *ad libitum,* barley grains, a commercial concentrate mixture and either clover hay or rice straw in separate feeders. Diet selection and food intake capacity were recorded. Dry packed volume, a suspension volume index, crude fibre content and indigestible crude fibre content remaining after 24 h *in situ* digestion of the foodstuffs were studied in a parallel laboratory experiment. Sheep consumed more barley grains than concentrate mixture whereas camels showed an opposite trend. Goats were practically similar to sheep, but they consumed the largest proportion of the roughage as compared to the other two species. Intake capacity per unit metabolic size was greater in sheep than in camels and goats. Across species, voluntary food intake was inversely related to crude fibre in the selected diets. However, all selected diets had similar packed volume values and suspension volume indices indicating the relationship between the fill properties of foods and the intake capacity of ruminant animals which is apparently valid across species.

Key words: Camels, goats, sheep, diet selection, food intake.

RESUME - *"Sélection du régime et capacité d'ingestion alimentaire chez des ovins, caprins et chameaux alimentés en stabulation individuelle, en rapport avec certaines propriétés physiques des aliments et leur digestion potentielle dans le rumen". Quatre chamelles, brebis et chèvres ont été alimentées* ad libitum *individuellement dans des nourrisseurs séparés avec du grain d'orge, un mélange de concentré commercial et, ou bien du foin de trèfle ou de la paille de riz. La sélection du régime et la capacité d'ingestion alimentaire ont été enregistrées. On a étudié dans une expérience parallèle en laboratoire le volume sec compacté, un index du volume en suspension, la teneur en fibre brute et la teneur en fibre brute indigestible qui restaient après 24 h de digestion* in situ *des aliments. Les brebis ont consommé plus de grains d'orge que de mélange de concentré tandis que les chamelles ont montré une tendance opposée. Les chèvres ont été semblables aux brebis, mais elles ont consommé la plus grande proportion de fourrages grossiers comparées aux deux autres espèces. La capacité d'ingestion par unité de taille métabolique a été plus grande chez les brebis que chez les chamelles et les chèvres. Au sein des espèces, l'ingestion alimentaire volontaire était inversement corrélée à la fibre brute dans les régimes sélectionnés. Cependant, tous les régimes sélectionnés avaient des valeurs de volumes compactés et des indices du volume en suspension semblables, comme indicateurs du rapport entre les propriétés d'encombrement des aliments et la capacité d'ingestion des ruminants, ce qui semble apparemment valable pour toutes les espèces.*

Mots-clés : *Chameaux, caprins, ovins, sélection du régime, ingestion alimentaire.*

Introduction

In nutrition experiments on camels the requirements of cattle in similar physiological states were invariably used. The requirements recommended by Wilson (1984) were also patterned after those for European breeds of cattle. It was not until the recent publication of the camel's maintenance requirements for energy and protein (Farid *et al.*, 1990; Farid, 1995) that feeding could be based on experimental findings. But maintenance is only one of the different physiological states of the animal and other states, e.g., growth, lactation and fattening, demand feeding at higher levels which require knowledge of the animal's feed intake capacity and its dietary preferences, both of which can be related to the physical, chemical and digestive properties of the feeds. The present communication reports findings from an experiment carried out to compare these faculties in dromedary camels, Barki sheep and local desert goats in an *ad libitum* cafeteria feeding experiment.

Materials and methods

Diet selection and voluntary food intake

Four dromedary she-camels, Barki ewes and local desert does were used in two consecutive trials. All animals were non-pregnant and non-lactating adults and were housed individually in shaded floor pens. Each trial lasted four weeks with two weeks in between. The first week was for preconditioning of animals to cafeteria feeding conditions and the following two weeks represented an adaptation period. Data of diet selection, voluntary food and free water intakes were recorded during the fourth week. Body weights were recorded at the beginning and end of each trial.

In the first trial animals were offered Egyptian clover (*Trifolium alexandrinum)* hay, a pelleted commercial concentrate mixture and cracked barley grains. In the second trial the hay was replaced with chopped rice straw. Foods were offered *ad libitum* and separated in divided feeders in order to allow for free selection by the animal and consequent recording of its intake from each foodstuff. Water was made available for one hour in the morning and daily free water intake was recorded. The proximate composition (AOAC, 1955) of the foods is presented in Table 1. Their nutritive values were calculated utilizing the equations of Kearl *et al.* (1979) for sheep.

Table 1. Average proximate composition and nutritive value (DM basis) and bulk indices of foodstuffs

Foodstuffs	Ash (%)	CP (%)	CF (%)	EE (%)	NFE (%)	ME (Mcal)	DP (%)	IDCF† (%)	PV (ml/g)	SVI (ml/g)
Rice straw	19.30	3.01	30.14	1.81	47.67	1.62	0	28.44	5.00	8.80
Clover hay	14.13	12.34	28.27	2.43	42.60	1.88	7.34	21.89	3.64	7.60
Concentrate mix	11.56	22.23	7.23	2.74	56.24	2.73	17.69	6.33	1.68	4.10
Barley grains	4.16	13.52	6.15	2.82	73.34	2.96	9.62	4.63	1.66	4.20

†24 h indigestible crude fibre content measured *in situ*

Physical and digestive properties of feeds

Two indices of the physical properties were measured in a parallel laboratory experiment. The first was bulk density estimated by the graduated cylinder method of Montgomery and Baumgardt (1965) and expressed, as the packed volume (PV) of the air-dry material, ml g^{-1}. The second, the suspension volume index (SVI), was developed in our laboratory to measure the volume occupied by the food after hydration in aqueous suspension. This was measured by suspending exactly 25 g air-dry ground sample in 300 ml tap water in a 500 ml graduated cylinder at room temperature. The suspension was stirred by a glass rod for approximately one minute every 10 minutes over a period of 90 minutes. The volume was then made up to the 500 ml mark with water, stirred once more taking care that no air bubbles were entrapped in the suspension and left to separate by gravity for 30 more minutes. The volume occupied by the suspended material, both the upper and lower phases, was recorded with the sum being the SVI expressed in ml suspended volume per g air-dry feed (ml g^{-1}).

Twenty-four hours *in situ* rumen digestion of crude fibre was carried out using conventional dacron bag technique in two fistulated rams fed a mixed diet of Egyptian clover hay and a pelleted commercial concentrate mixture at slightly above maintenance. The contents were analysed for crude fibre using official procedures (AOAC, 1955). Measurements were carried out in duplicates in each animal to estimate the 24 h indigestible crude fibre content (24IDCF%) of the feeds used in the *in vivo* experiment (Table 1).

Results and discussion

Animal performance

Relative weight changes are summarized in Table 2. Camels and sheep in the hay groups gained similarly, those in the straw groups gained less, a decrease of 23% in camels and 50% in sheep. Goats in the hay group did not perform as well and lost weight even though their intake was above maintenance requirements as indicated below, whereas those in the straw group deteriorated fast and that treatment had to be discontinued.

Table 2. Voluntary food intake, diet selection and characteristics and free water intake†

	Camels		Sheep		Goats
	Hay	Straw	Hay	Straw	Hay
Live body weight (kg)	530	527	65.9	56.9	40.9
Metabolic size ($kg^{0.73}$)	97.44	97.03	21.27	19.11	15.02
Weight change (g d^{-1} 100 kg^{-1})	523	401	510	256	-140
Dry matter intake					
Total (g day^{-1})	8493	7653	2107	1765	968
Concentrate mix (%)	55.9	69.2	16.4	32.3	22.4
Barley grains (%)	31.1	18.5	70.7	62.9	44.3
Roughage (%)	13.0	12.3	12.9	4.8	33.3
Daily intake (per $kg^{0.73}$)					
DM (g)	87.16	78.56	99.06	92.36	64.45
ME (kcal)	39	208	276	261	164
DP (g)	12.07	11.06	10.55	10.86	6.88
Intake, multiples of maintenance††					
Energy (ME)	2.32	2.02	2.56	2.42	1.47
Protein (DP)	4.16	4.29	3.94	4.05	2.56
Characteristics of selected diets					
ME (Mcal kg^{-1} DM)	2.74	2.64	2.79	2.83	2.54
DP (g 100 $kcal^{-1}$ ME)	5.05	5.32	3.82	4.16	4.71
CF (%DM)	10.01	10.74	9.27	8.30	13.17
24IDCF (%DM)	7.82	8.74	7.14	6.32	10.76
PV (ml g^{-1})	1.93	2.08	1.92	1.83	2.32
SVI (ml g^{-1})	4.59	4.70	4.62	4.39	5.71
Free water intake					
ml g^{-1} DMI	2.02	2.67	2.08	2.21	2.12
ml $(kg^{0.82})^{-1}$	100.1	119.9	141.5	141.8	98.0

†Values are averages from four animals in each group
††Energy (kcal ME) and protein (g DP) maintenance requirements per $kg^{0.73}$. Camels, 103 and 2.58 (Farid, 1995); Barki sheep, 108 and 2.68 (Farid *et al.*, 1983) and goats, 111 and 2.69 (Kearl, 1982)

Voluntary food intake and diet selection

Voluntary food intake (VFI) was greater in sheep than camels whereas goats consumed the least. Also, animals in the straw groups consumed less total DM as compared to their mates in the hay groups (Table 2). On average, camels consumed 13.3% less DM than sheep, and straw feeding decreased VFI 9.5% in camels and 6.8% in sheep. Goats had the lowest total DM intake. However, these changes need to be considered along with changes in diet selection indicated below. Kearl (1982) reported average values of 70 and 68 g DM day^{-1} $(kg^{0.73})^{-1}$ for sheep and goats breeds of

developing countries, respectively. Maximum *ad libitum* intake values reported for dromedary camels in our previous experiments (Farid, 1995) amounted to 83.2 g DM day^{-1} $(kg^{0.73})^{-1}$, similar to free choice intakes reported in the present experiment (Table 2).

Diet selection, on the other hand, was radically different between camels and sheep. Camels consumed more of the higher protein concentrate mixture than from barley grains, whereas sheep showed an opposite trend in both hay and straw treatments (Table 2), except that it represented a greater proportion in straw fed animals, possibly to compensate for the lower nitrogen content of straw. The proportion of barley grains in total VFI was less in camels than sheep, and less in straw fed animals than in their hay fed mates.

Hay comprised 13% of total VFI in both camels and sheep. When offered straw, camels nearly maintained its roughage proportion in total VFI, being 12.3%, whereas in sheep it decreased to only 4.8%.

Goats represented a special case. Roughage percentage from hay was as high as one third of their *ad libitum* DM intake, possibly contributing to their lower total VFI because of physical limitation of the rumen. They resembled sheep in their diet selection, consuming less concentrate mixture than barley grains.

Energy and protein intakes

Energy and protein contents of the selected diets were calculated from values presented in Table 1. Intake per unit metabolic size and as multiples of the maintenance requirements of each species are presented in Table 2. Energy intake was less in camels than sheep, and was distinctly low in goats compared to both camels and sheep offered the hay roughage. Also, animals in the straw groups consumed less energy than their mates fed hay.

Digestible protein (DP) intake, was slightly more in camels than in sheep, and was not apparently affected in the straw fed groups as those animals increased their consumption from the higher protein concentrate mixture. Goats had the lowest protein intake.

Energy and protein intakes were compared to established requirements for the maintenance of live body weight of dromedary camels (Farid, 1995), Barki sheep (Farid *et al.,* 1983) and the goat breeds of developing countries (Kearl, 1982). Irrespective of roughage treatments and species, with the exception of goats, energy intake was about 2.0-2.5 times their maintenance requirements. Protein intake was four times their maintenance requirements, indicating possible preference for foods with higher protein content (Cropper *et al.*, 1985, 1986). These intakes were conducive of the observed performance in terms of gain in weight as indicated above.

Goats, although consumed 1.5 and 2.5 times their maintenance requirements of energy and protein they lost weight when fed the clover hay as roughage, and the experiment had to be terminated for the straw group. There is no simple explanation for this poor performance of goats under the present experimental conditions in comparison with either camels or sheep.

Characteristics of selected diets

The characteristics of diets selected free choice by the three species are summarized in Table 2. Energy density, Mcal ME kg^{-1} DM, was remarkably constant. Differences between camels and sheep and between hay and straw groups were negligible, being less than 4%. Although goats' VFI was low and with larger proportion of roughage, the energy density of their selected diet was not practically different from the other two species.

The protein-energy ratio was in favour of camels compared to sheep. Goats fed clover hay were intermediate. According to established maintenance requirements cited above, the protein-energy ratio of maintenance diets was constant for the three species ranging between 2.4 and 2.5 g DP 100 $kcal^{-1}$ ME, considerably lower than the observed values at free choice *ad libitum* intake.

It was of interest to examine differences in the content of crude fibre (CF%) and 24 h indigestible crude fibre (24IDCF%) of diets selected by the three species. Also the differences in the physical properties of the selected diets, indicative of rumen fill, namely the packed volume (PV) and the suspension volume index (SVI), both in ml g^{-1} (Table 2). In all cases, the free choice selected diets were low in crude fibre. In goats offered clover hay it was somewhat greater than in the other two species. Only goats nearly approached the recommended minimum level of dietary CF content for the proper functioning of the rumen, being approximately 15-17% on dry matter basis. The 24IDCF content of the selected diets followed the same pattern as the CF content.

The volume indices of the selected diets were practically constant in camels and sheep (SVI range: 4.4-4.7 ml g^{-1}) and about 20% greater in goats (5.7 ml g^{-1}). The dry packed volume (PV) followed a similar trend (Table 2). The relationships between fibre contents and volume indices of the selected diets and the voluntary food intake of the animals can be observed from data presented in Table 2. The general trend was that VFI decreased as the CF% and 24IDCF% increased. On the other hand, PV and SVI of the selected diets were remarkably constant irrespective of the animal species or the type of roughage offered. These findings are in general agreement with the classical reports on the physical-physiological regulation of voluntary food intake in ruminant animals (Conrad *et al.*, 1964; Montgomery and Baumgardt, 1965; Farid and Hassan, 1976; Forbes, 1995).

Free water intake

Free water intake, ml g^{-1} DMI, was not practically different between the three species when fed the clover hay but increased when fed straw. When expressed per unit body mass, ml $(kg^{0.82})^{-1}$, it was 41.4 and 18.3% greater in sheep than camels when fed hay and straw, respectively. Goats were similar to camels. Straw feeding increased it in camels only by 19.8%. The reported values are possibly minimal and not reflecting the true differences between species in their natural environment since the animals were housed indoors.

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