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Selection of diets by dual-purpose Mamber goats in Mediterranean woodland

D. KABABYA[1], A. PEREVOLOTSKY[2], I. BRUCKENTAL[3] AND S. LANDAU[2]*

[1] *Ministry of Agriculture, Extension Service, Sheep and Goats Department, PO Box 7054, Tel Aviv 61070, Israel*

[2] *Department of Natural Resources, Institute of Field and Garden Crops, Agricultural Research Organization, The Volcani Center, PO Box 6, Bet Dagan 50250, Israel*

[3] *Department of Physiology and Nutrition of Dairy Cattle, Institute of Animal Science, Agricultural Research Organization, The Volcani Center, PO Box 6, Bet Dagan 50250, Israel*

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SUMMARY

The feeding behaviour of Mamber dairy goats grazing on Mediterranean woodland in the Upper Galilee mountains of Israel was studied throughout a year (1991/92). The percentages of crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and condensed tannins (CT) were determined in samples collected by hand to simulate the plant parts selected by the goats. Total feed intake was evaluated by using Cr-sesquioxide as an external marker to determine the amount of faeces excreted, and 48 h *in sacco* degradability to assess the digestibility of samples. Overall, more time was spent by goats in feeding on ligneous material (tree and shrub foliage) than herbaceous vegetation (60 and 40% of total feeding time, respectively, $P < 0{\cdot}05$). The main ligneous species consumed by the goats were *Quercus calliprinos*, *Sarcopoterium spinosum* and *Calicotome villosa* (20, 13 and 7% of total grazing time, respectively). There was considerable variability in the 48 h dry matter (DM) *in sacco* degradability, and in the concentration of CP, NDF, ADF, ADL and CT, within and between seasons and plant species. Although requirements for nutrients varied according to the physiological stage of the goats, 48 h *in sacco* DM degradability and the concentration of non-ADF linked (available) CP, NDF, ADF, ADL and CT in the diet did not vary greatly: respective ranges were 45·0–49·4; 9–12·5; 44–53; 33–39; 12–17 and 3·5–4·7%. It is concluded that Mamber goats (i) may not select the best quality diet available, but may avoid wide variations in nutrient content of their diets throughout the year; and (ii) may not select a diet consistent with maximization of milk yield, but rather with optimization of body condition at the onset of the mating season.

INTRODUCTION

Mamber goats are native to the Upper Galilee mountains of Israel and their main source of food is East Mediterranean rangeland. They are commonly regarded as being very well adapted to their environment. They yield only *c.* 130 litres of milk after weaning of kids. Attempts to improve milk yield by giving liberal amounts of concentrates during lactation have invariably failed, because the goats refused to consume them, or became over-fattened, but did not significantly increase their milk yield (reviewed by Landau *et al.* 1995). The first step needed to improve milking performance in these goats is, therefore, to clarify what are the components of their natural diet during a complete cycle of production, in order to determine which nutrients are likely to limit production.

Herbivores feeding on rangeland may show two main alternative foraging strategies which differ in the degree of selectivity. One possible strategy is to maximize the quality of the forage consumed, i.e. to choose plants or parts of plants of high crude protein (CP) content and high digestibility of dry matter (DM), although the rate of intake may be low. Another strategy is to consume greater amounts of a poorer quality, thus achieving higher rates of food intake within a short time. The first strategy involves the risk of not achieving a sufficiently high nutrient intake. The second strategy is especially helpful if total grazing time is limited, for example if there is a

* To whom all correspondence should be addressed. Email: vclandau@volcani.agri.gov.il

risk of predation. However, a major problem inherent with this strategy is that of matching the quality of the diet (which may be limiting if the main species available are deficient in an important nutrient) with nutritional requirements. Large ruminants, having larger gut capacities, longer retention times of food particles in the digestive tract, and greater ability to digest poor forage than small ruminants (see review by O'Reagain & Schwartz (1995)), generally exhibit less selective feeding behaviour than small ruminants. Kyriazakis & Oldham (1993) showed that when allowed to choose a diet from two foods differing in CP content, lambs selected diets that promoted high rates of accretion of lean mass in the short term. This would suggest that when the requirements of goats for proteins are high, as in lactation, they would select a diet high in CP, which, on the Eastern Mediterranean rangelands, would mean feeding almost exclusively on lush green grass, when available. Such behaviour was not observed by Kababya *et al*. (1992) in Anglo-Nubian goats nor by A. Perevolotsky (unpublished) in Mamber goats on Eastern Mediterranean rangeland. This raises questions about the feeding strategy being adopted by goats in this environment.

The aims of this study were therefore to define the seasonal composition of diets, to quantify the intake of nutrients throughout the year and to gain an understanding of the foraging strategy of dual-purpose Mamber goats grazing Eastern Mediterranean rangelands.

MATERIALS AND METHODS

Site description

The study was carried out from November 1991 to October 1992 on a herd of Mamber goats located at Matat, in the northern Galilee region of Israel (33·1° N, 35·2° E; elevation 840 m). Rainfall during the study was 1300 mm from October to May. Three snow days were recorded in February and the ground was covered with snow for 6 days. The growing season of vegetation was from mid-March to mid-June.

Habitats

The rangeland ecosystem at Matat is Mediterranean woodland and scrubland (garrigue), characterized by steep, rocky slopes with patches of shallow soil. The vegetation is dominated by low trees (mainly *Quercus calliprinos*, *Styrax officinalis* and *Pistacia palaestina*) and shrubs (mainly *Calicotome villosa*, *Rhamnus punctata* and *Sarcopoterium spinosum*). The grazing area was classified into five sub-habitats. The herbaceous sub-habitat was covered mainly (> 80 %) by herbaceous vegetation, with *Avena* spp., *Trifolium campestre*, *Lolium perenne*, *Dactylis glomerata* and *Hordeum bulbosum* as the most frequent species. The dense Mediterranean woodland was covered mainly (> 60 %) by trees, usually *Q. calliprinos*. The sparse Mediterranean woodland was covered partly (> 30 %) by trees and partly by herbaceous vegetation. The heavily grazed Mediterranean woodland (an overgrazed area, usually near buildings and water points) was characterized by dwarf *Q. calliprinos* trees and no growth of herbaceous species, even during the green season. The garrigue sub-habitat was covered mainly (> 80 %) by shrubs, usually dominated by *S. spinosum*.

Animals and management

Sixty-two local Mamber female goats of a commercial flock of 360 does were selected following positive pregnancy diagnosis. All goats were grazed as a flock each day from 06.00 to 18.00 h on a fenced area of 200 ha (0·55 ha/head). Does were housed on a dust floor in a roofed building (*c*. 1·50 m^2/head) by night. Goats were not herded but guard Maremma dogs were present in the herd at all times. Kidding started on 5 January and ended on 23 January (weighted average 15 January). All kids were identified and weighed three times until weaning at *c*. 60 days of age. The kids had free access to their mothers, except when does were outdoors at pasture, until once-daily milking started on 5 March. At that date, they were allowed to suckle at night only. The does were milked twice daily after kids were weaned (from 20 March to September). Goats were supplemented with 400 g/head per day of a commercial concentrate (16 % CP) from mid-December until mid-April.

Liveweight (LW) and body condition score (BCS), estimated on a lumbar site (0–5 scale; Santucci *et al*. (1991)) were recorded six times. Milk production before weaning was estimated from kid weight gain, assuming a 1·1:1 ratio between milk ingested (DM basis) and weight gain by kids (Havrevoll *et al*. 1991). After weaning, milk production was recorded monthly, using a flow-meter calibrated for goat-milk (Goat milk meter, Waikato Milking Systems, Interag, Hamilton, New Zealand).

Observations and analyses

This study monitored diet selection in terms of the species selected relative to those encountered along the search path of the foraging animal. The choice of search path within the foraging habitat is beyond the scope of this study and, of course, may reflect a degree of selection relative to the foraging environment as a whole. Feeding behaviour was monitored on 90 days between November 1991 and October 1992. Three to six observations of 10–30 min duration each were carried out on an observation day. Observations were distributed equally throughout the grazing hours. Goats were identified by hair discoloration achieved

with liquid nitrogen. Observations were made from a distance of 0·5–1·5 m. Goats were chosen for observation at random. The presence of the observer had no detectable effect on the grazing activity and social relationships of goats since they were accustomed to handling, including hand-milking. At the start of an observation, the date, hour, goat number, weather conditions and foraging habitat were recorded using a portable tape-recorder. The nature and starting time of all activities were then recorded for the duration of the observation. Possible observations were standing (without grazing), walking, resting in shaded areas and grazing at a feeding station. A feeding station could be a single tree, shrub or herbaceous patch but each record of an encounter between goats and vegetation corresponded to a vegetation unit of $0{\cdot}50 \times 0{\cdot}50$ m, in order to standardize for size of species. Trees with foliage above the browsing reach of the animal were not recorded. Species, consumed, duration of eating and species avoided were recorded at each observation. Not all plants were identified at the species level. In particular, herbaceous species were group defined only as 'herbaceous'. The criterion for an encounter was for part of a plant to be within 0·5 m reach of the animal's head (Cooper *et al*. 1988). When an animal started to eat (termed a 'grazing encounter'), the observer recorded 'eat' and the species (or species grouping) grazed or browsed. The relative frequency of encounter for a species was defined as the ratio of the number of encounters with this species to the total number of encounters with all species during an observation. The relative frequency of encounter with a species is different from true relative cover since the search path of the animals cannot be regarded as random. Bite count and size could not be recorded for all eating bouts because goats were sometimes partially hidden by the vegetation, especially when browsing in dense shrub or tree thickets. In order to estimate the quality of the diet selected by the goats, a hand-simulated grazing technique was employed. During the course of the experiment, the allocation of daily foraging time by species was averaged once each season from the recorded observations. The observer then gathered bite-like samples of those species over the course of a grazing day according to the computed relative foraging times. This was achieved by following individual goats and clipping or plucking bite-like samples at the same rate as the observed goat, so that the correct total grazing time for each species was achieved over the course of the day. This was done in three replicates. In order to estimate the quality of the species on offer in the foraging environment, samples of species on which $> 5\%$ of grazing time had been spent were gathered monthly. Dry matter (DM) was obtained by drying samples in a ventilated oven at 60 °C for 3 days. Samples were then ground in a Wiley mill, using a 1 mm sieve, and analysed for CP ($N \times 6{\cdot}25$; AOAC 1984), acid detergent fibre (ADF), neutral detergent fibre (NDF), and acid detergent lignin (ADL) according to Goering & Van Soest (1970). ADF-linked protein analysis was carried out according to Hogan & Lindsay (1980). Condensed tannins (CT) were analysed according to Hagerman & Butler (1978). Digestibility was assessed using *in situ* disappearance of DM from samples incubated for 48 h in the rumen of cows, as described by Arieli *et al*. (1989).

The estimation of intake was conducted on 15 goats on four occasions (December, April, June and August). The amount of faeces excreted was determined using chromium oxide as an inert, undigested tracer. Plastic-coated chromium III oxide (Bruckental *et al*. 1989) was mixed with ground corn and pelleted. Each goat was fed individually 50 g of pellets, containing 150 mg Cr, at 06.00 h, before they were turned out to pasture. On each occasion in which intake was estimated, pellets were fed to the goats for 10 days and faecal samples collected for the last 3 days of each period. Faeces were sampled from the rectum twice daily at random, between 18.00 and 06.00 h. Samples (six per goat) were pooled for each goat within a 3-day sampling period. Faecal samples were dried at 60 °C for 3 days. Samples were then ground in a Wiley mill, using a 1-mm sieve, until analysed for chromium III oxide according to Stevenson & de Langen (1960).

Samples of faeces were collected before Cr-oxide administration, analysed for Cr, and concentrations of samples collected during Cr administration corrected for background concentrations of Cr. The amount of faeces excreted per day was calculated as (dose per day of Cr)/(corrected concentration of Cr in faeces). Feed intake was estimated from the amount of faeces excreted and the digestibility of the diet, assuming concentrate had a DM digestibility of 80 %. Therefore,

$$\text{Intake at pasture (g DM per day)} = \frac{(\text{TF} - 20\text{S}/100)100}{(100\text{–DMD})}$$

where TF = total daily dry matter faeces (g/day) produced, S = intake of supplementary concentrate (g DM/day) DMD = digestibility of DM (%).

Statistics

Data for all traits were analysed by least squares. The effect of season on the percentages of time spent grazing different plant species was assessed by analysis of variance, using the Duncan's multiple range test in the General Linear Models (GLM) procedure of SAS (1985). The analysis of variance for milk yield, LW, BCS and feed intake was conducted by using a repeated measures procedure, with goat (season) as the error term in the GLM procedure.

Table 1. *Percentage of time spent grazing plant species (least square means)**

Overall ($n = 360$)		Autumn ($n = 99$)		Winter ($n = 80$)		Spring ($n = 86$)		Summer ($n = 95$)	
Herbaceous vegetation	29·3	Acorns†	28·1	Herbaceous vegetation	33·3	Herbaceous vegetation	42·7	*Quercus calliprinos*	26·0
Quercus calliprinos	20·9	*Quercus calliprinos*	24·8	*Quercus calliprinos*	23·6	*Quercus calliprinos*	11·9	*Rhamnus punctata*	14·0
Sarcopoterium spinosum	12·7	Herbaceous vegetation	18·2	*Sarcopoterium spinosum*	21·5	Forbs	9·4	Herbaceous vegetation	11·1
Calicotome villosa	6·9	*Sarcopoterium spinosum*	17·8	*Calicotome villosa*	6·8	*Calicotome villosa*	8·4	Spiny species	10·0
Spiny species	5·8	*Cistus* spp.	3·5	Forbs	5·1	Spiny species	8·1	*Calicotome villosa*	6·3
Rhamnus punctata	5·1	*Calicotome villosa*	3·3	Fungi	3·4	*Sarcopoterium spinosum*	6·4	*Styrax officinalis*	6·1
Forbs	4·9	Forbs	2·1	Spiny species	2·0	*Rhamnus punctata*	2·9	*Sarcopoterium spinosum*	5·9
Acorns†	2·4					*Crataegus* spp.	2·5	*Pistacia palaestina*	4·7
Cistus spp.	2·1							Vines	4·2
								Cistus spp.	3·6
								Crataegus spp.	2·5

* Only species which were grazed for $> 2\%$ of the total grazing time are represented.
† From *Quercus calliprinos*.

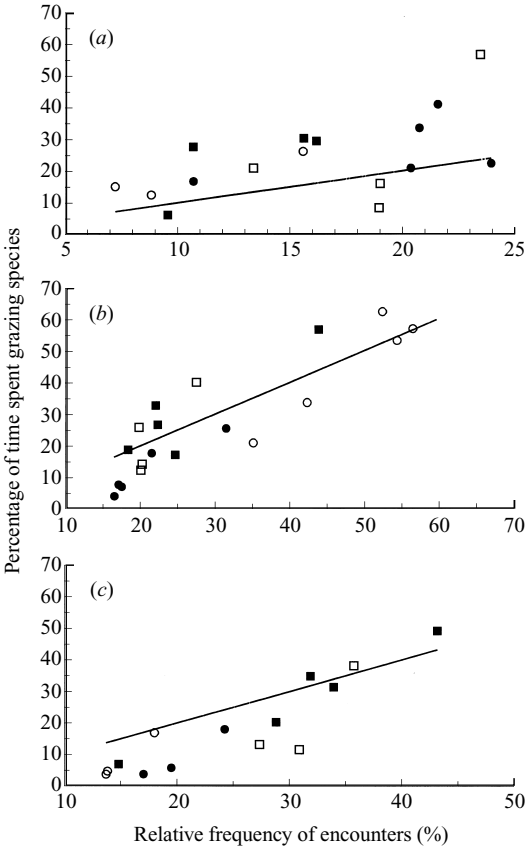

Fig. 1. The percentage of time spent grazing (*a*) *Quercus calliprinos*, (*b*) herbaceous species and (*c*) *Sarcopoterium spinosum* in relation to relative frequency of encounter in autumn (□, $n = 89$), winter (■, $n = 80$), spring (○, $n = 86$) and summer (●, $n = 95$). Each point represents the mean of all observations on individual goats for each of the five habitats on the site. The line represents $y = x$.

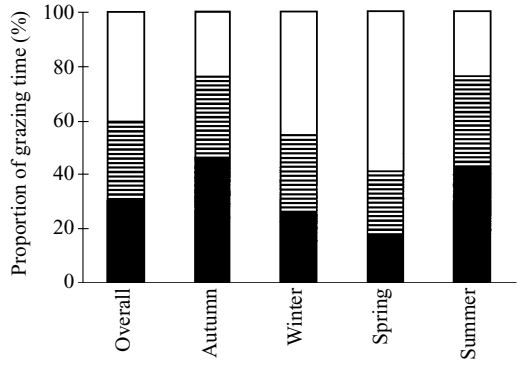

Fig. 2. Percentage of time spent grazing trees (■), shrubs (▤) and herbaceous vegetation (□) in each season.

RESULTS

On an annual basis, the goats spent *c*. 20% of the grazing time consuming *Q. calliprinos*, although this proportion was lowest (*c*. 12%) in spring. The percentage of time spent grazing *S. spinosum* and *C. villosa* was 12·7 and 7%, on a yearly basis, respectively (Table 1). The relative frequency of encounter of a species by goats on the range was strongly related to the time spent foraging on it. However, the proportion of time spent feeding on foliage of *Q. calliprinos* was slightly more (Fig. 1*a*), and on *S. spinosum* less (Fig. 1*c*), than could be predicted by the relative frequency of encounter with goats, whereas time spent feeding on herbaceous vegetation corresponded well with the relative frequency of encounter (Fig. 1*b*). Overall, goats spent less time at feeding on herbaceous, compared with ligneous (tree and shrub leaves) vegetation (40 and 60%, respectively, $P < 0{\cdot}05$; Fig. 2). This was the case in all seasons with the exception of spring (April–May).

Although the range of CP concentration in the five main different plants was considerable (Fig. 3*a*), concentrations in the reconstituted diet only varied from 10·0 to 14·6%. This range is even narrower if ADF-insoluble CP is subtracted (9–12·5%). The same tendency was observed for NDF: the maximum was 53% and the minimum was 44% (Fig. 3*b*). ADF in the diet ranged between 32·7 and 38·7% (Fig. 3*c*). ADL ranged between 12 and 17% (Fig. 3*d*). The range in CT was relatively small, ranging between 3·5 and 4·7% (Fig. 3*e*). The range of DM digestibility in the diets was much narrower (45–49·4%) than the range (29–76%) found in the vegetation (Fig. 3*f*).

Intake of DM was lowest in December, increased from December until April, remained steady from April to June and was greatest in August ($P < 0{\cdot}05$; Table 2). In spite of low DM intake, CP intake was as

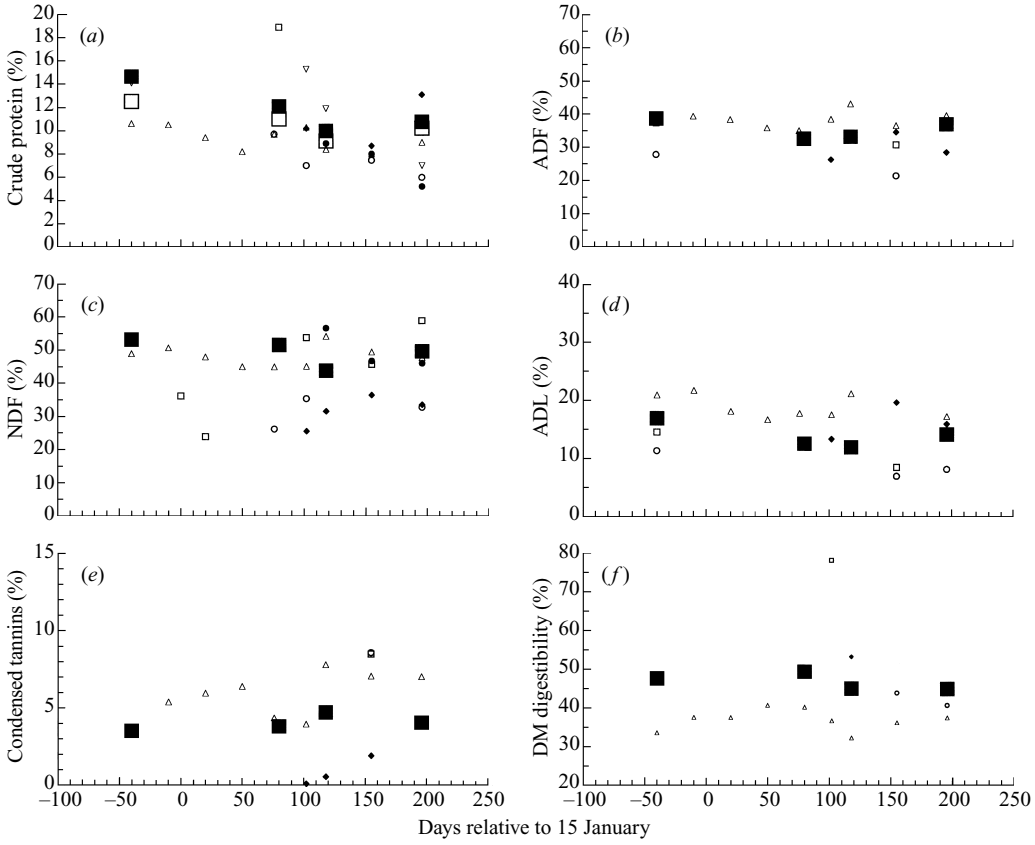

Fig. 3. Concentrations (% of DM) of (*a*) crude protein (CP) and non-ADF-linked CP (□), (*b*) acid detergent fibre (ADF), (*c*) neutral detergent fibre (NDF), (*d*) acid detergent lignin (ADL), (*e*) condensed tannins (CT) and (*f*) DM digestibility in the selected diet (■) and in the main species encountered by goats on the range: *Quercus calliprinos* (△), *Sarcopoterium spinosum* (○), *Rhamnus punctata* (◆), *Calicotome villosa* (□), thorns (●) and herbaceous species (▽); $n = 390$. Day 0 is the mean kidding date (15 January).

Table 2. *Estimated daily intake of pasture dry matter (DM, kg/day), crude protein (CP, g/day), digestible protein (DP, g/day) and digestible energy (DE, Mcal/day)*

	DM	CP	DP	DE
Dec	1·04	148	90	2·13
Apr	1·35	160	83	2·89
Jun	1·29	131	65	2·62
Aug	1·48	160	83	2·93
S.E.	52	6·1	3·2	0·11
D.F.	14	14	14	14

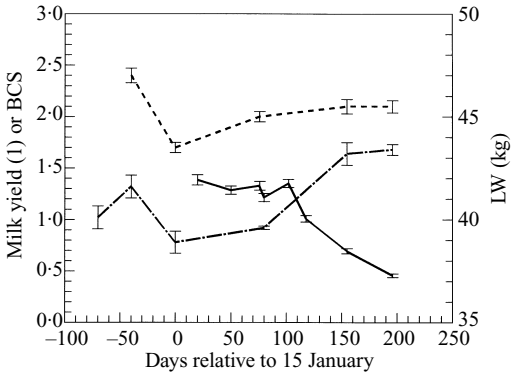

Fig. 4. Liveweight (LW, kg, –·–), body condition score (BCS, scale 0–5, - - -) and milk yield (litres/day, ——) relative to kidding date (15 January, on average; least square means ± S.E., $n = 62$).

high in December as in April or August. The intake of CP plateaued between December and April, decreased between April and June and increased between June and April. Intake of digestible energy was lower in December than in all other periods. Estimated DM intake amounted to 2·5, 3·2, 2·9 and 3·3% of LW in December, April, June and August, respectively.

In spite of the concentrate supplementation, a significant ($P < 0·05$) decrease in LW (2·7 kg) was recorded in the last 6 weeks of pregnancy (Fig. 4), concomitantly with a loss in condition (0·6 point of BCS ($P < 0·05$)). The goats gained significantly ($P < 0·05$) in condition, but not in weight, during the first 6 weeks *post-partum* and condition plateaued at 2·0 points thereafter. LW recovered abruptly from the beginning of April, after weaning of the kids, although concentrate supplementation was discontinued and milk yield was at its highest. Milk yield plateaued at 1·25–1·35 kg until 24 April and fell ($P < 0·01$) to 1·0 kg in mid-May (i.e. *c.* 120 days *post-partum*). The decrease in milk yield continued until milk control was discontinued, on 2 August. On that date, milk yield averaged 0·5 kg.

DISCUSSION

The Mamber goats in this study spent 60% of their feeding time at pasture, browsing ligneous vegetation (Fig. 2). This is consistent with the hypothesis that even though goats can be productive on an all-herbaceous diet, as they are in some production systems (e.g. in western Europe), they will not choose a diet consisting of only herbaceous plants if tree and shrub foliage is also available. The data presented here agree with previous results established in Mamber goats bred in a similar environment, in which browsing shrubs and trees represented 62% of the time spent feeding (reviewed by Landau *et al.* (1995)). Similar results were obtained by Nefzaoui *et al.* (1993) working on Alpine × local Tunisian goats and by Nastis (1987) on Greek goats. In a previous study by Kababya *et al.* (1992), Anglo-Nubian goats supplemented with 1 kg of concentrates, spent less time grazing herbaceous species than did Mamber goats in the present study (16 *v.* 40%, respectively), but a similar proportion of foraging time was spent browsing *Q. calliprinos*, *S. spinosum* and *C. villosa* (35 *v.* 40% found in the present study). It is possible, therefore, that concentrates fed to dairy goats have a negative effect on the time spent feeding on herbaceous vegetation, without affecting the proportion of time spent on the three main ligneous species of vegetation. In all periods of the year, the diet was composed of numerous plant species (Table 1). French workers have shown that the meals of goats in Mediterranean woodlands are organized in bouts of 20–30 min browsing the more frequently chosen species and 5–10 min periods of browsing on other species. This may allow for maximal intake of DM (Meuret *et al.* 1995). Ruminants do not seem to 'memorize' the nutritional characteristics of different species on the range. Ingestion of small amounts of the various species every day may be a mechanism by which animals can check for post-ingestive consequences, especially when changes in nutritional quality are very rapid (Dumont 1995). This is especially important in ranges that have been subjected to high grazing pressures until recently, such as the Galilee range, and where plants have developed high concentrations of secondary metabolites to deter herbivores from grazing (Perevolotsky 1994).

Three main dietary factors are involved in determination of feed intake in herbivores; CP and NDF concentrations and DM digestibility (Ketelaars 1986). A fourth one, tannin content, is more characteristic of browse in a Mediterranean context (Perevolotsky 1994; Silanikove *et al.* 1996). The finding that the concentration of these components is almost constant throughout the year (Fig. 3) is consistent with results from a previous, more restricted study with Anglo-Nubian goats (Kababya *et al.* 1992), in which dietary CP ranged between 10·3 and

12·6%, and DM digestibility between 45 and 52%. During the period of maximal feed requirement, the CP requirement, calculated according to the NRC (1985) and using actual BW and milk yield (Fig. 4), was 160 g/day, which was consistent with the CP intake in April (Table 2). When translated into percentage units, a dietary CP content of 12% meets this requirement. If only grass was consumed, goats would have selected a diet containing 15% CP, comparable to the concentration of CP needed by high-yielding dairy cows (NRC 1989). The intake of NDF relative to $LW^{0·75}$ in the present study ranged between 33 and 43·8 g/kg $LW^{0·75}$, averaging 39 g/kg $LW^{0·75}$. This is in agreement with observations on dairy cows by Bywater (1984), that free intake of NDF at pasture tends to be constant at 40 g/kg $LW^{0·75}$, regardless of NDF concentration in the feed. However, in order to maximize milk yield in dairy cows, dietary NF must not be > 28–30% (NRC 1989).

The present study (Fig. 3*e*) showed that free-ranging goats tend to select components of their diet such that the CT concentration in the total diet remained relatively constant throughout the year. The optimal concentration of CT in diets for ruminants is controversial: on the one hand, scientists in New Zealand have recently established that an optimal balance between the negative (protein-binding, depression of carbohydrate digestion) and the positive (improvement of N digestion) effects of tannins is achieved in sheep when their dietary concentration is *c*. 3–4% (Barry *et al*. 1986; Wang *et al*. 1996). On the other hand, recent research in Israel has shown that neutralization of tannins in the diets of Mamber goats fed the foliage of *Q. calliprinos*, *P. lentiscus* or *Ceratonia siliqua* (carob) using polyethylene glycol (PEG) results in increased feed intake, increased digestibility of DM, CP and NDF, and improved energy balance (Silanikove *et al*. 1996). Nutrient intake for maximization of milk yield would imply selection of more grass at periods of maximal requirement. Therefore, patterns of diet selection in Mamber goats are not compatible with milk yield maximization.

Milk yield decreased abruptly in June (Fig. 4), concomitantly with the reduction in intake of CP and digestible protein (Table 2). A similar decrease was noted in Anglo-Nubian goats browsing Mediterranean shrubland, independent of the amount of concentrate supplementation (Landau *et al*. 1993). Interestingly, in the present study, CP intake was greater in August than in June. Feed availability is assumed to be less in August than in June, because it never rains in Israel after June and most herbaceous biomass consists of dead material after June. Energy intake did not vary in the same period. In contrast to energy, protein cannot be stored long term in goats. Therefore, a decrease in CP intake is followed immediately by a drop in milk yield (Fig. 1), which in turn results in increased LW and BCS, fuelled by the steady intake of energy. It seems, therefore, that goats select a 'self dry-off and fattening' diet in June, enhanced by the increase in DM intake between June and August. The onset of the mating season of Mamber goats occurs naturally in August. This suggests that the long-term metabolism of Mamber goats is directed at improving the chance of reproductive success by reaching a high BCS and LW after day 150 *post-partum*, at the onset of the mating season (Fig. 4). It may seem paradoxical that more than 5000 years since domestication, Mamber goats still select dietary components in a way that fits the goals attributed by Westoby (1974) to large herbivores free-roaming in the wilderness (i.e. obtaining large amounts of different nutrients, in the appropriate proportions, from a relatively fixed bulk ingested) and share with wild animals the objective of successful breeding. However, selection of goats by man in harsh Mediterranean environments was traditionally based more on lifetime performance and adaptivity of breeding performance to seasonal events, such as transhumance, than on individual milk production (Santucci 1984). In such selection schemes, the ability of goats to recover quickly from lactation and conceive early in the next season was emphasised.

In summary, Mamber goats selected diets that are consistent with low milk yield and tend to maximize the probability of being bred early in the mating season. This feature may be the product of long-term genetic selection by traditional farmers in the East Mediterranean region.

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