Foraging selectivity of three goat breeds in a Mediterranean shrubland

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Abstract

Foraging behaviours of the Damascus, Mamber and Boer goat breeds were compared on the South Carmel mountain ridge in Israel. Dietary choice was determined for a group of 10 or 11 yearling animals of each breed, housed and grazed separately to prevent social facilitation, during a total of 4 (Mamber) or 5 (Damascus and Boer) 4-day periods in the fall of 2004 and spring of 2005. The proportions of the three main dietary components – *P. lentiscus* L. (20% tannins), *Phillyrea latifolia* L. (3% tannins) and herbaceous species (as a single category) in the diet (which also included concentrate) were determined by application of near-infrared reflectance spectroscopy to faecal samples ("faecal NIRS") (n = 129). On average, *P. lentiscus* accounted for 13.0% of the dry matter ingested by Damascus goats, but only 5.0% and 4.9%, respectively, of that ingested by Mambers and Boers (Damascus > Mambers = Boers, $P < 0.0001$). Damascus goats ingested diets richer in tannins (5.4% vs. 4.2%, respectively, $P < 0.0001$). The contribution of herbaceous species to ingested DM in the spring was higher in Mambers than in the other breeds (33% vs. 27%, respectively). Boer goats selected the most nutritious diets in terms of crude protein (CP) content and in-vitro dry matter digestibility (IVDMD). In spite of their differences in foraging selectivity, the local Damascus and Mamber goats had similar dietary percentages of CP and similar IVDMD. Our data suggest that the Damascus is a preferred candidate to control *P. lentiscus* encroachment and is the least likely to compete with cattle for green grass in the spring. These findings may contribute to the attempt to find ecologically sound ways of controlling the spread of the tannin-rich shrub *Pistacia lentiscus* L., which threatens rangeland biodiversity and amenity values in the Mediterranean climatic region of Israel.
Keywords: Goat, Browse, Mediterranean Woodland, Near-Infrared Spectroscopy

1. Introduction

Different livestock species exhibit differences in grazing behavior and will consume different plant species or plant groups when exploiting the same pastures (Abaye *et al.* 1994; Taylor, 1985). Domestic goats (*Capra hircus*) ingest browse even when more nutritious food, such as alfalfa hay, is available (Landau et al., 2002). However, the propensity to browse may differ between breeds within the domestic goat species.

When comparing Spanish and Angora goats, Pritz et al. (1997) found that Spanish goats exhibited higher consumption of redberry juniper (*Juniperus pinchotii Sudw.*) than did Angora goats. Grazing behaviour differences between breeds may also be related to sensitivity to worm burdens; Hoste et al. (2001) found that when kept in heterogeneous environments, Saanen goats behaved as browsers more than did Angora goats, and Saanens had lower worm burdens than did Angoras.

A major managerial issue of Mediterranean rangelands is related to brush encroachment. Most brush species have developed various strategies to cope with herbivory. Some of them, such as *Phillyrea latifolia* L. a small tree approximately 4 m in height, exhibit vigorous re-growth when browsed but have low tannin content. Others, such as the tall shrub *Pistacia lentiscus* L, a strongly encroaching species, synthesize secondary compounds, especially tannins (20% tannins, on dry matter basis; Landau et al., 2004a), which deter browsing (Decandia et al., 2000; Landau et al., 2002).

Two indigenous and one recently imported breed of goats are potential candidates to combat *P. lentiscus* encroachment in Israel. The local, small-framed Mamber goat thrives on Mediterranean brushland (Aharon

et al., 2007) and has developed complex feeding behaviours to regulate its dietary concentration of tannins (Kababya et al., 1998), but it ingests *P. lentiscus* in small amounts when given it as the sole feed source (Silanikove et al., 1996). On the other hand, the large-framed Damascus goat can ingest large amounts of *P. lentiscus* (Landau et al., 2002). Little is known about the dietary preference of the recently introduced, large-framed Boer goat in this environment (Aharon et al., 2007). The foraging behaviour of these three breeds, while grazing *P. lentiscus*-encroached areas, has never been compared.

A methodology based on the spectral characteristics of faeces in the near infra-red region and termed "F.NIRS" has recently been shown to reliably predict botanical and nutrient composition of the diets of goats fed Mediterranean browse (Glasser et al., 2008). This methodology has been upgraded to be useful in freely ranging goats by constructing calibration equations of intake based on bite-counting and simulated bite mass (Glasser et al., 2008). The aim of the present study was to use this new approach to compare the foraging selectivity (botanical and nutritional) of Mamber, Damascus and Boer goats in a landscape dominated by *P. latifolia,* where tannin-rich *P. lentiscus* is increasingly encroaching.

2. Materials and Methods

2.1. Study Site and Nutritional Characteristics of the Main Botanical Components

The study was conducted at the Ramat Hanadiv nature park which is located on the southern tip of the Carmel mountain ridge, Israel (32°25' N,34°52'E), characterized by an average yearly rainfall of 600 mm, and a 180 day rainy season from October to April. The ecosystem is a garrigue, featuring steep rocky slopes with rare patches of shallow soil. The vegetation is dominated by low trees (mainly *Phillyrea latifolia* L.) and tall shrubs (*Pistacia lentiscus* L. and *Calicotome villosa* L.) which form 2- to 3-m high round coppice islets that are sometimes covered with climbing *Rubia tenuifolia* Dum.-Urville, *Clematis cirrhosa* L. and *Smilax aspera* L. From January to mid-May, green annual herbaceous vegetation covers the soil patches.

The herbaceous species *P. latifolia* and *P. lentiscus* (as a single category) are the major dietary components selected by goats in the above foraging environment. The nutritional quality of the herbaceous species plummets between spring and summer, with summer crude protein (CP) concentration and in-vitro dry matter digestibility (IVDMD; determined according to Tilley and Terry, 1963), as low as 7.1% and 44%, respectively (Landau et al., 2005). The nutritional quality of ligneous vegetation is more stable.

2.2. Animals and Grazing Management

Groups of Damascus, Boer and Mamber yearlings were brought from farms where goats grazed daily. The breeds were housed and grazed separately in order to prevent social facilitation, and were kept according to the Israel Council on Animal Care Guidelines (ICACG, 1994). The goats grazed for approximately 4 hours daily. The animals received a daily ration of 138 g dry matter (DM) concentrate (Ambar Feed Mills, Hadera, Israel) containing 18% CP, on a DM basis. Boer, Mamber and Damascus goats weighed 21 kg (SE 1.1), 18.1 kg (SE 0.7), and 31.8 kg (SE 0.5), respectively, in the of 2004; and 31.6 kg (SE 1.7), 26.7 kg (SE 0.5), and 36.4 kg (SE 0.7), respectively in the spring of 2005.

Over the course of fall 2004 and spring, 2005, foraging was rotated among seven 0.1-ha paddocks, according to vegetation availability, in order to expose each breed to each paddock in the same season.

2.3. NIRS-aided Calibrations of the Botanical Composition of Diets

Faecal near infra-red spectroscopy (F.NIRS) calibration equations (Glasser et al, 2008) featured reasonable precision for determining dietary percentages of the three main botanical components, i.e., herbaceous ($R^2 = 0.85$), *Phillyrea latifolia* ($R^2 = 0.89$), and tannin-rich *Pistacia lentiscus* ($R^2 = 0.77$), with SE of cross-validation (SECV) values of 7.8%, 6.3%, and 5.6% of DM, respectively. The R^2 values for the faecal NIRS calibrations of CP, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), IVDMD, and PEG-binding tannins (Landau et al., 2004b) were 0.93, 0.88, 0.89, 0.91, and 0.74, respectively, with SECV values of 0.87%, 2.1%, 1.7%, 4.3%, and 0.88%, respectively, of ingested DM.

2.4. Prediction of Foraging Selectivity and Nutritional Attributes in Goats

In the fall of 2004 and spring of 2005, faecal samples were grab-collected individually from all of the animals in each group. A total of 129 faecal samples was collected and dietary attributes calculated by

subjecting them to NIRS scanning, using the published F.NIRS calibrations (Glasser et al., 2008). Two records of putatively sick goats were withdrawn from this collection.

2.5. Statistical Analyses

F.NIRS predictions of the botanical and nutritional composition of the goats' diets were analyzed by a blocked repeated measures analysis of variance (ANOVA) with the GLM procedure of SAS (1989). Factors in the model were breed (Damascus, Mamber, or Boer), season (fall or spring; as the repeated effect), season × goat-within-breed, paddock (as a block effect), and the season × breed interaction. The error term for the analysis of breed was goat-within-breed. The error term for the analyses of season and season × breed was season × goat-within-breed. For factors having more than two levels, differences between means were subjected to Tukey's HSD test.

3. Results and Discussion

Dietary Percentages of Nutritional Attributes - Significant effects of season, paddock and breed × season were found for all examined attributes of dietary chemical composition. The nutritional value of the selected diets was superior in spring to that in fall, with the former having a higher CP concentration (13.4% and 8.1%, respectively, $P<0.001$) and higher IVDMD than the latter (67% and 43%, respectively, $P < 0.001$). The ingested diets had lower contents of PEG-binding tannin, ADF, and NDF in spring than in fall (Figure 1; $P < 0.001$). The diets selected by Damascus goats contained on a DM basis 2.0 percentage units less ($P < 0.01$) CP than those of the Boers, but did not differ from those of the Mambers (Figure 1); the Boers' diets were also higher in IVDMD than those of the other two breeds (Figure 1). The percentage of dietary PEG-binding tannins was higher ($P<0.001$) in the Damascus' diets (5.4%) than in those of the Mambers and Boers (4.2%). Interestingly, the Mamber and Boer goats maintained their dietary tannin concentrations within narrow ranges when they switched from spring to fall diets: between 4.4% and 3.9% of ingested DM for the Mambers, and between 4.1% and 4.5% for the Boers. In contrast, Damascus goats' dietary intake of PEG-binding tannins increased from 4.6% to 6.0% of ingested DM (Figure 1).

Dietary Percentages of P. lentiscus, P. latifolia*, and herbaceous species - P. lentiscus* accounted for 7.4% of ingested DM, on average. Breed, season, and their interaction were significant for the dietary percentage of *P. lentiscus*, with breed being the most prominent main effect ($P < 0.001$). Overall, tannin-rich *P. lentiscus* provided 5.0% and 9.8%, of the DM ingested in spring and fall, respectively ($P < 0.001$). Damascus goats ingested a higher dietary percentage of *P. lentiscus* than Mambers and Boers: 13.0%, 5.0%, and 4.9 % of DM, respectively ($P < 0.001$). Damascus and Boer goats consumed more *P. lentiscus* in fall than in spring. For these breeds a significant ($P < 0.001$) breed × season interaction was obtained, however this seasonal effect was not observed in Mamber goats (Figure 2).

The most frequently ingested plant was *P. latifolia*, which contributed more than one-fifth of the total ingested DM on a yearly average. The most dominant factor affecting its dietary percentage was season. Goats selected diets that contained four times as much *P. latifolia* in fall than in spring, i.e., 34.9% and 8.5% of ingested DM, respectively ($P < 0.001$). Dietary percentages of *P. latifolia* also differed between the breeds ($P < 0.001$). Averaged across both seasons, *P. latifolia* contributed 14.8%, 25.6%, and 26.5% of the ingested DM to the diets of the Boer, Mamber, and Damascus goats, respectively ($P < 0.001$) (Figure 2).

On average, herbaceous vegetation represented 23.4% of the goats' diets. Season had a strong effect on the herbaceous content of the selected diets (26.8% in spring vs. 15.1% in fall, $P < 0.001$; Figure 2). The breed effect was significant, with diets of Mamber and Damascus goats containing a higher proportion of herbaceous plants than that of Boers (24.0% and 22.2% of ingested DM, respectively, $P < 0.01$; Figure 2). The contribution of herbaceous vegetation to ingested DM in the spring was significantly higher in the Mambers than in the other breeds (33% vs. 27%, respectively, $P < 0.001$).

During summer the two main foraging resources on the southern ridge of the Mount Carmel range are *P. latifolia* and *P. lentiscus*. We contend that tannins are the primary factor that limits intake of *P. lentiscus*, because when such a diet was supplemented with polyethylene-glycol (PEG), a polymer which specifically alleviates the deleterious effects of tannins on intake, caged Mamber goats almost doubled their intake of the shrub (Silanikove et al., 1996). Damascus and Sarda goats also greatly increased the time they spent freely foraging on *P. lentiscus* once supplemented with PEG (Landau et al., 2002; Decandia et al., 2000). Because of the short duration of the green season, goats consume spring, summer and fall diets for 3, 6 and 3 months,

respectively. Therefore, after weighting of spring and summer diets on a yearly basis, Damascus goats will probably ingest diets approximately twice as high in *P. lentiscus* as those of Boers and Mambers. This strongly suggests that Damascus goats are more appropriate candidates to control *P. lentiscus* encroachment in shrubland than are the other breeds. Interestingly, the concentrations of PEG-binding tannins in the diets of Boer and Mamber goats reported in the present study are well within the range of 3% to 4% of DM considered by Barry and McNabb (1999) to be optimal for intestinal absorption of amino acids.

One possible explanation for the superiority of Damascus goats in tackling the tannin problem may be found in their desert origins (Mason, 1984), as desert goats recycle urea more efficiently than do others (Silanikove et al., 1980). Another, somewhat anecdotal explanation may be found in the differing management systems of the breeds. Mamber goats are managed in large flocks. They are milked, but rarely kept in confinement because they yield only ca. 150 L of milk and one kid per year, and do not justify investment (Landau et al., 1995). Damascus goats typically yield 450 L/yr, are more prolific, and are often kept in confined, small flocks to provide milk for the household. Therefore it is less time-consuming for breeders to provide them with cut browse than with grass. Also, browse is available all year round, in contrast with grass. This difference in upkeep practices may have resulted in adaptation to selection pressure to overcome the negative effects of dietary tannins. According to this interpretation, the behavioral differences which were observed regarding the propensity to consume tannin-rich forage is rooted in cognitive behaviors that reflect physiological between-breed differences and previously established acquired behaviors. This hypothesis should be more deeply explored.

4. Conclusions

The data presented here suggest that Mamber and Boer goats are effective consumers of Mediterranean browse, but not of tannin-rich *P. lentiscus*. The two local Mediterranean goats of breeds, i.e., the Damascus and Mamber goats, which have evolved in tannin-rich environments, are not identical in their propensity to consume the encroaching *P. lentiscus*, even though they select diets of equal nutritional quality. Therefore, if control of *P. lentiscus* is the main reason for restoring goats to shrublands, Damascus goats should be preferred.

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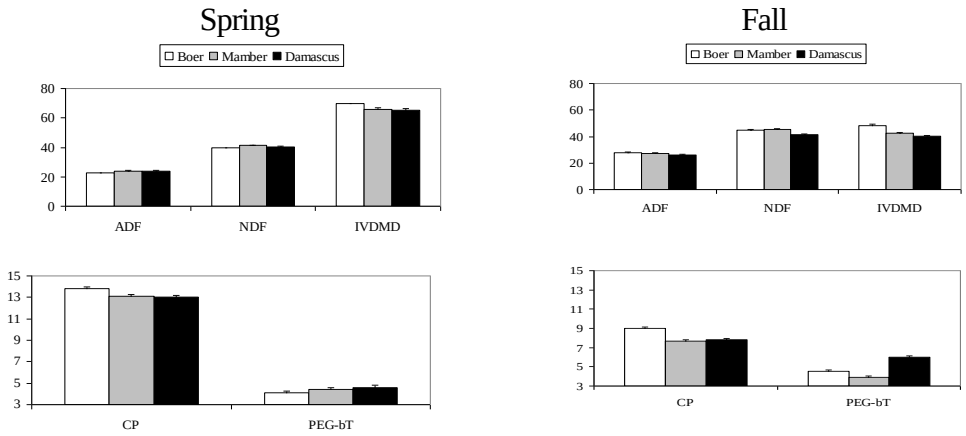

Figure 1. : Proportions (% of ingested DM) of Crude Protein (CP), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), In Vitro Dry Matter Digestibility (IVDMD), and PEG-binding tannins in the diets of goats grazing in the Mount Carmel shrubland, predicted by F.NIRS (n=129) Y-axis: % of ingested DM.

Spring **Fall**

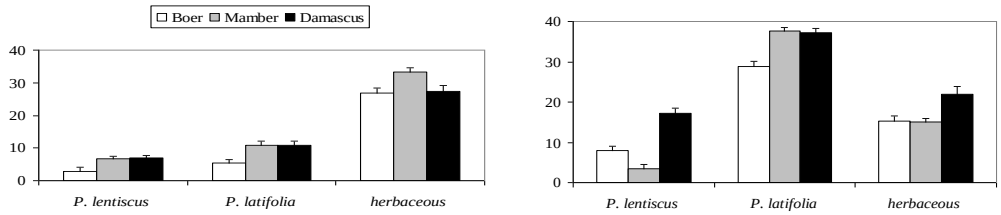

Figure 2: Proportions (% of ingested DM) of P. lentiscus, P. latifolia, and herbaceous species in the diets of goats grazing in the Carmel heights shrubland, predicted by faecal NIRS (n=129). Y-axis: % of ingested DM