Small Ruminant Research 103 (2012) 152–157

Contents lists available at SciVerse ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Effect of the physiological state of Criollo goats on the botanical composition of their diet in NE Mendoza, Argentina

L. Allegretti[a,b,*], C. Sartor[b], S. Paez Lama[a], V. Egea[a], M. Fucili[a], C. Passera[b]

[a] Instituto Argentino de Investigaciones de las Zonas Áridas (IADIZA), CC 507 (M5502BPB), Mendoza, Argentina
[b] Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo, Alte. Brown 500, CC 7 (M5528AHB), Chacras de Coria, Mendoza, Argentina

ARTICLE INFO

Article history:
Received 23 February 2010
Received in revised form 21 July 2011
Accepted 9 September 2011
Available online 1 October 2011

Keywords:
Desert rangeland
Microhistology
Nutritive value
Grazing behaviour

ABSTRACT

The botanical composition of the diet and species preference of grazing goats in different physiological states were evaluated in the autumn and winter seasons. The study was performed in a desert rangeland in the northeast (NE) Mendoza region in Argentina. Food availability was estimated from forage species cover. Rectal grab faecal samples were collected from goats, and the botanical composition of the goat diet was determined using a microhistological technique. Goat preferences for each species consumed were calculated based on Ivlev's index. Nutritional composition and secondary compounds of forage species were determined. Correlations between diet and availability; and between goat preference and nutritional composition of forage species were also estimated. The habitat consisted of a dominant woody stratum associated with an herb stratum primarily composed of grasses. Goats in different physiological states utilised a significantly higher proportion of woody vegetation compared to grass ($p < 0.01$). When grass availability was high (autumn), the herb stratum was more utilised by pregnant and lactating goats than by dry goats ($p < 0.05$). In the winter, the diet of lactating goats consisted of more *Atriplex lampa* compared to the diet of dry goats ($p < 0.05$), probably due to the high crude protein content of the plant. Goats consumed forage species with highly variable total phenol and tannin contents, which did not negatively affect selection. Correlations between diet and availability were high in the winter for dry ($r_s = 0.88$, $p < 0.02$), pregnant ($r_s = 0.93$, $p < 0.01$) and lactating goats ($r_s = 0.97$, $p < 0.01$) but were not significant in the autumn. A significant correlation between preference and crude protein was shown during the autumn season for pregnant and lactating goats ($r_s = 0.6$, $p < 0.05$). Forage availability was the main factor influencing diet selection in this arid environment. When food availability was not a limiting factor, goats selected a diet that most closely matched their nutritional requirements. Physiological state modified nutrient requirements and affected diet selection in that pregnant and lactating goats selected forage species with high protein contents.

1. Introduction

Goats are particularly important in arid zones, with attributes such as versatility in harvesting a wide range of native browse and herbaceous species, ability to walk long distances compared to other livestock species and the preferential selection of a highly nutritional diet and digestible plant parts (Lebbie, 2004; Lu, 1988; Ramírez-Orduña et al., 2008). Under grazing conditions, herbivores consume a

* Corresponding author at: Instituto Argentino de Investigaciones de las Zonas Áridas (IADIZA), CC 507 (M5502BPB), Mendoza, Argentina. Tel.: +54 261 5244164; fax: +54 261 524 4101.
E-mail address: lia@mendoza-conicet.gov.ar (L. Allegretti).

0921-4488/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.smallrumres.2011.09.018

varied diet composed of species with different nutrient and toxin concentrations (Distel and Villalba, 2007; Emmans, 1991; Provenza et al., 2003).

Long-term changes in the physiological state of the animal, such as pregnancy and lactation, can cause shifts in diet selection (Church, 1988; Mellado et al., 2005). This shift may be due to the different nutritional requirements and voluntary food intake that occurs during the phases of the animal's reproductive cycles (Forbes, 1995).

In the arid areas of the northeast (NE) Mendoza region in Argentina, the most important economic activity is goat husbandry, which is managed using extensive production systems (Guevara et al., 2006). Shrublands and open woodlands play an important role because they provide forage materials for grazing animals throughout the year. These areas are characterised by a long dry period (April–September) and harsh environmental conditions. Animal and dietary factors affecting diet selection in these environments are not completely understood. The aim of this study was to determine the botanical composition of the diet and species preference of native goats in different physiological states that graze in a desert rangeland.

2. Material and methods

2.1. Study site

This study was performed in the farmer household of "La Majada" (32°19′39′S, 67°54′36′W). Criollo goats were managed using extensive grazing systems of over approximately 2500 ha. The trees and shrubs most commonly found in the area include algarrobo dulce, *Prosopis flexuosa* (DC); chañar, *Geoffroea decorticans* (Gill. ex Hook.) Burkart; retamo, *Bulnesia retama* (Hook. & Arn.) Gris.; atamisque, *Capparis atamisquea* (Kuntze); zampa, *Atriplex lampa* (Gill. ex Moq); usillo, *Tricomaria usillo* (Gill. ex Hook. ex Arnott) and pichana, *Mimosa ephedroides* (Gill. ex Hook. & Arn.) Benth. The primary grass species include pasto de hoja, *Trichloris crinita* (Lag. Parodi); plumerito, *Pappophorum caespitosum* (R. Fries) and tupe, *Panicum urvilleanum* (Kunth). The vegetation communities of major foraging importance with regard to floristic composition, forage species cover and carrying capacity are semi-closed woodlands of *P. flexuosa* with *A. lampa* in interdune valleys and open woodlands of *P. flexuosa* with *A. lampa* and *T. usillo* on dunes (Alvarez et al., 2006; Passera et al., 2004). Rainfall is mostly torrential and occurs primarily in the summer. The mean annual rainfall is 159 mm, and the mean annual temperature is 18.3 °C (Villagra et al., 2005). The growing season rainfall from October 2005 to March 2006 was 80.4 mm, while the mean growing season rainfall is 120.9 mm (1971–1994, 2001–2008). Data were obtained from the Telteca Reserve weather station (32°20′S, 68°00′W). Soils in the study area are mainly sandy with undifferentiated horizons (Entisols and Aridisols).

2.2. Animals and management

For the present study, Criollo goats from a commercial meat flock were used ($n = 250$). Goats grazed in an open range from 8.30 to 17.00 h and were penned near the household in the evening with access to water. Autumn–winter (April–August) is the main parturition season. The mean annual kid crop is 0.8–1.0 goat^{-1}, and kids are weaned at 60 days old at 9–11 kg in body weight.

The two sampling periods in 2006 occurred at the beginning of the parturition season in the autumn (April) and near the end of the season in the winter (July). During each sampling period, six dry goats (non-lactating and non-pregnant), six lactating does (from 30 days of the birth of their kids) and six pregnant goats in late gestation (about 100 days of pregnancy) were identified for collection of faecal samples. Different animals were used for each sampling season. The selected goats were 36 ± 2.8 kg in body weight and had similar parity (>3 parturitions). The goats walked 2.5–6 km daily followed by a shepherd who protected the herd from predators, such as foxes and pumas. The most important forage species in the zone were present at the grazing site within a range of approximately 500 ha. This large area prevented over-grazing of vegetation and provided the goats with free dietary choices without any influence among animals. Once at the grazing site, the shepherd stayed away from the goats without influencing their grazing behaviour. The goats grazed at the same site consisting of woodlands of *P. flexuosa* with *A. lampa* and *P. flexuosa* with *T. usillo* in both seasons.

2.3. Food availability

Food availability was estimated at the same time as the faecal sampling using vegetation cover as an approximate measure of availability (Kufner et al., 2008). Forage species cover was estimated using the point quadrat method (Daget and Poissonet, 1971), which was modified for the Monte area by Passera et al. (2007). At the grazing site, ten 50-m randomly distributed transects were established, and 100 points (50 cm apart) were monitored per transect in each season. The intercepting species at each point were recorded with a needle. The proportion of contact of each species was considered an estimate of coverage. For each species consumed by goats, the mean plant cover was calculated by season, and plant species were grouped into two categories, grasses and shrubs plus trees.

2.4. Diet analysis and specific selectivity

During each sampling period, rectal faecal samples were collected from individual animals (approximately 10 pellets). Five faecal samples were collected from each goat over five successive days. Samples were dried at 70 °C for 72 h, ground in a Willey mill and passed through a 1-mm screen. The five samples were mixed together, and one subsample per goat was analysed. The botanical composition was determined using a microhistological technique (Holechek et al., 1982; Sparks and Malechek, 1968). Two microscope slides were made for each sample, and 50 fields of view were systematically located on each slide at 400× magnification, resulting in 100 fields per sample. A reference plant collection was used for plant identification (Guevara et al., 2010; Monge, 1989).

In order to identify the plant parts consumed by the goats, two grazing animals from each group were directly observed for 2 days during both seasons for 10-min periods every 30 min (Genin and Pijoan, 1993). These observations were made to determine the nutritional composition of the plants eaten by the goats. Ten plants were sampled, and one composite sample was made for each species to determine the dry matter (DM) and crude protein (CP) contents (AOAC, 1990). Organic matter digestibility (OMD) and neutral detergent fibre (NDF) were determined in the Laboratory of Nutrition and Forage Quality Assessment, EEA INTA Balcarce. Total phenols (TP) and total tannins (TT) were analysed according to the Folin–Ciocalteu method (Makkar, 2010).

Preference values were calculated for each species consumed based on Ivlev's (1961) electivity index as follows: (% species in diet − % species availability)/(% species in diet + % species availability). Plants were classified according to this index into the following categories: preference (+1.0 to +0.3), indifference (+0.3 to −0.3) and avoidance (−1.0 to −0.3) (Puig et al., 2001).

2.5. Statistical analysis

The numbers of epidermal fragments of each species as recorded by microhistological analysis were converted to percentages. Data on forage species cover and percentage of plant species in the diet were transformed to arcsin-root to normalise the distribution (Steel and Torrie, 1980). One-way ANOVA and Tukey's multiple comparison tests were used to detect differences between the animal groups. The sampling unit was the individual goat ($n = 6$), and the physiological state and seasons were considered factors. Spearman's rank correlation test was used to determine the relationship between seasonal forage availability and relative frequency of species occurrence in the diet and the relationship between goat preference (Ivlev's index) and nutritional composition. Data were analysed using InfoStat statistical software (InfoStat, 2004).

Overlap in diet composition was estimated using Kulczynski's similarity index as follows: $\mathrm{KSI} = 100 \sum 2c_i / \sum (a_i + b_i)$, where c_i is the lesser percentage of the i component in the two diets and $(a_i + b_i)$ is the sum of the percentages of each plant component in both diets (Oosting, 1956).

Table 1
Mean contribution of forage species to food availability (%).

	Autumn	Winter
Atriplex lampa	21.0	12.5
Bulnesia retama	8.7	0.3
Capparis atamisquea	4.6	18.8
Geoffroea decorticans	5.7	12.5
Lycium spp.	4.6	0.9
Mimosa ephedroides	4.6	12.5
Prosopis flexuosa	6.6	7.8
Tricomaria usillo	21.4	25.1
Total shrubs and trees	77.2	90.6
Aristida mendocina	2.6	–
Panicum urvilleanum	9.2	3.1
Pappophorum caespitosum	3.1	3.1
Setaria spp.	2.3	–
Trichloris crinita	5.7	3.1
Total grasses	22.8	9.4

Values are means calculated from field transects ($n = 10$). Empty cells indicate non available species.

3. Results and discussion

3.1. Food availability

The study area consisted of a dominant shrub stratum associated with an herb stratum composed primarily of grasses. Food availability (forage species cover) in the autumn was 37%, with shrubs and trees contributing 77% and grass contributing 23%. In the winter, availability decreased significantly to 17.5% ($p < 0.05$), with over 90% involving woody forage species. Availability of each species was variable depending on the season (Table 1). In the autumn, at least 13 species were available for consumption by the goats, while in the winter only nine were available (availability of *B. retama* and *Lycium* spp. were considered negligible). *T. usillo* was the most available species during both seasons.

3.2. Diet analysis and specific selectivity

The botanical composition of the goat diet (Table 2) in all physiological states in both seasons had a significantly higher percentage of shrubs and trees than grasses ($p < 0.01$). During the beginning of parturition (autumn), more shrub and tree species were consumed by dry goats than by lactating and pregnant goats ($p < 0.05$). Dayenoff et al. (1997) also observed a higher proportion of woody species (71.7%) than grasses (22.7%) in the diet composition of Criollo goats under arid grazing conditions in Arid Chaco, Argentina, during the dry season in the winter.

When grass availability was high (autumn), the herb stratum was more utilised by pregnant and lactating goats than by dry goats ($p < 0.05$). The proportion of *P. urvilleanum* in the diet of pregnant and lactating goats was higher than that in the diet of dry goats ($p < 0.05$), likely because *P. urvilleanum* remained in vegetative growth longer and may have improved the quality of the diet because the CP values of *P. urvilleanum* were moderately higher when compared to the protein values of other grasses in the area (Guevara et al., 2009). Pregnant and lactating goats likely selected grasses to satisfy their protein requirements. This type of vegetation represents a species that is appropriate for pregnant goats (Mellado et al., 2005, 2006).

Inclusion of grasses in the goat diet is related to availability. Therefore, it is more appropriate to classify goats as "opportunists" and mixed feeders than grazers or browsers (Dziba et al., 2003; Lu, 1988; Rogosic et al., 2008).

T. usillo, supplemented with *P. flexuosa*, *C. atamisquea* and *A. lampa* and *M. ephedroides*, was the main shrub in the diet of goats in both seasons and for all physiological states, probably due to its high availability in the field (Table 2). In the winter, lactating goats utilised *T. usillo* less ($p < 0.05$) than pregnant and dry does, and *A. lampa* was present in higher proportion in the diet of lactating does than in the diet of dry and pregnant goats ($p < 0.05$). *M. ephedroides* was used in higher proportions by dry and pregnant goats compared to goats that were lactating ($p < 0.05$) (Table 2).

The woody species in this study are generally considered to have an intermediate nutritional quality because they contain approximately 40% OMD, 10% CP, and between 33.2 and 60% NDF (Table 3). These values are similar to those reported by Van den Bosch et al. (1997). The leaves, twigs and immature fruits of *B. retama* and *Lycium* were available only in the autumn and were likely consumed due to their high protein contents (Table 3). Plant phenology could influence the availability of food and daily food intake; goats, as selective feeders, become adapted to changes in the feeding conditions (Becker and Lohrmann, 1992).

In the winter, the increased inclusion of evergreen shrubs (*A. lampa*, *C. atamisquea*) in the diet could be due to their crude protein contents compared to *T. usillo* (12.8 and 13.5 vs. 7.2%, respectively). The nutritional requirements of lactating ruminants are as much as five times higher than their normal maintenance requirements (Forbes, 1986). *P. flexuosa* had high protein levels during both seasons. Because these trees lose their leaves during the winter, the goats consumed the leaves that had fallen on the ground (Table 3).

Goats consumed a wide array of plant species, including forage species with highly variable contents of TP and TT (Table 3). Although *T. usillo* and *M. ephedroides* were the most frequently consumed species in the winter, they had had high TP and TT levels (Table 3). Under the study conditions, these secondary compounds did not negatively affect diet selection. Goats are capable of eating tannin-rich browse species due to their ability to neutralise the negative effect of tannins (Launchbaugh et al., 2001; Provenza et al., 2003; Silanikove, 2000). A behavioural strategy for coping with high secondary compounds is the composition of the mixed diets, which include plant species with low concentrations of the compounds (Estell, 2010).

Correlations between diet and availability were high in the winter for dry ($r_s = 0.88$, $p < 0.05$), pregnant ($r_s = 0.93$, $p < 0.01$) and lactating goats ($r_s = 0.97$, $p < 0.01$) (Fig. 1a and b). When food availability was low (winter), goats had fewer selection opportunities and food availability was the major determining factor in diet composition. Although goats have species preferences, in this situation, their diets are closely related to the available forage (Animut and Goetsch, 2008; Dziba et al., 2003; Papachristou et al., 2005). The close relationship between the diet of goats and arid

Table 2
Diet botanical composition (%) for dry, pregnant and lactating goats in autumn and winter.

Species	Autumn Dry	Pregnant	Lactating	Winter Dry	Pregnant	Lactating
Atriplex lampa	12.56 ± 1.8	9.23 ± 3.7	9.08 ± 3.9	8.47 ± 3.3a	10.29 ± 6.4a	16.38 ± 1.6b
Bulnesia retama	6.78 ± 0.7	3.70 ± 1.2	5.04 ± 3.1	–	–	–
Capparis atamisquea	14.05 ± 3.7	14.04 ± 0.6	11.16 ± 0.7	17.11 ± 5.9	21.20 ± 3.7	24.05 ± 4.1
Geoffroea decorticans	0.57 ± 1.0	–	–	0.36 ± 0.8	0.29 ± 0.7	0.71 ± 2.2
Lycium spp.	5.05 ± 3.0	4.55 ± 2.8	5.08 ± 1.8	–	0.26 ± 0.6	–
Mimosa ephedroides	–	–	0.51 ± 1.0	25.90 ± 4.5a	23.47 ± 3.8a	18.12 ± 5.2b
Prosopis flexuosa	12.64 ± 2.6	14.37 ± 6.6	13.21 ± 1.1	11.82 ± 3.8	8.30 ± 3.2	9.78 ± 2.1
Tricomaria usillo	40.50 ± 2.7	38.71 ± 3.5	38.54 ± 2.3	34.58 ± 3.0a	35.64 ± 3.0a	28.18 ± 3.4b
Total shrubs and trees	92.14 ± 8.3a	84.60 ± 8.9b	82.62 ± 10.0b	98.24 ± 6.9	99.44 ± 10.1	97.22 ± 13.5
Aristida mendocina	0.50 ± 0.9	–	2.08 ± 3.6	–	–	–
Panicum urvilleanum	3.22 ± 1.8a	8.40 ± 1.5b	12.13 ± 3.8b	1.43 ± 3.1	0.56 ± 0.9	–
Pappophorum caespitosum	2.64 ± 1.0	3.50 ± 3.1	0.63 ± 1.0	0.33 ± 0.7	–	2.44 ± 2.6
Setaria spp.	0.50 ± 0.9	1.52 ± 1.5	1.02 ± 3.6	–	–	–
Trichloris crinita	1.00 ± 1.7	1.98 ± 2.2	1.52 ± 0.9	–	–	0.34 ± 0.8
Total grasses	7.86 ± 1.6a	15.40 ± 4.7b	17.38 ± 8.0b	1.76 ± 3.1	0.56 ± 0.9	2.78 ± 3.1

Values are means ± SD ($n = 6$). Values in the same row with different letters differ significantly ($p < 0.05$).
Empty cells indicate that plant species were not utilised by goats.

Table 3
Chemical composition (%DM) of plant parts consumed by goats in autumn and winter.

Species	Autumn Plant part consumed	OMD	CP	NDF	TP	TT	Winter Plant part consumed	OMD	CP	NDF	TP	TT
A. lampa	LT	71.3	10.0	33.2	nd	nd	LTF	65.4	12.8	39.2	1.4	nd
B. retama	LTF	53.8	17.0	41.5	nd	nd	NC	–	–	–	–	–
C. atamisquea	LT	40.2	15.4	50.1	1.2	1.3	LT	35.1	13.5	59.5	1.5	nd
G. decorticans	LTF	42.5	18.5	44.6	12.07	1.3	L^{-1}	38.2	12.5	45.9	9.3	3.1
Lycium spp.	LTF	55.2	16.4	59.1	nd	nd	L^{-1}	27.8	8.6	75.9	nd	nd
M. ephedroides	B	32.2	10.9	52.8	27.6	6.5	B	31.2	8.4	55.1	15.3	7.0
P. flexuosa	LT	37.1	14.0	39.7	4.2	2.6	L^{-1}	32.3	12.6	50.1	3.2	0.7
T. usillo	LT	40.9	10.5	48.8	20.4	7.3	TL	33.3	7.2	55.3	15.1	8.3
P. urvilleanum	LS	37.5	7.2	60.0	nd	nd	LS	25.5	5.4	72.9	nd	nd

B, upright branches; L^{-1}, leaves on the plant or fallen on the ground; LS, leaves and stems; LT, leaves and twigs; LTF, leaves, twigs and immature fruits; TL, green twigs and dry leaves, on the plant or fallen; NC, non-consumable; OMD, organic matter digestibility; CP, crude protein; NDF, neutral detergent fibre; TP, total phenols; TT, total tannins, and nd, not detected. Empty cells indicate that plant species were not utilised by goats.

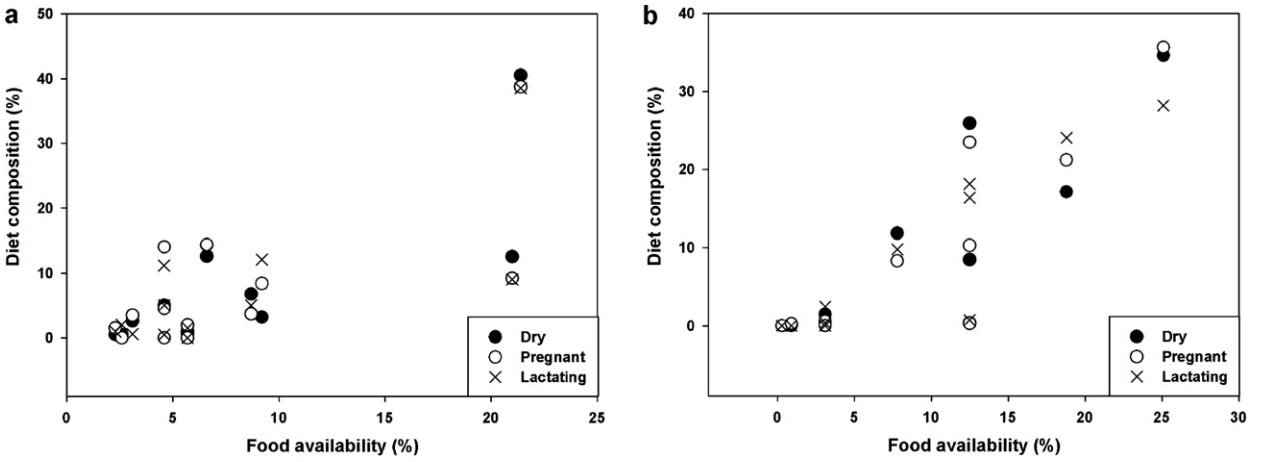

Fig. 1. (a) Relationship between food availability (proportion of forage species in the field) and goat diet composition (proportion of consumed species in the diet). Forage species consumed by dry, pregnant and lactating goats in autumn were: *Atriplex lampa*, *Bulnesia retama*, *Capparis atamisquea*, *Geoffroea decorticans*, *Lycium* spp., *Mimosa ephedroides*, *Prosopis flexuosa*, *Tricomaria usillo*, *Aristida mendocina*, *Panicum urvilleanum*, *Pappophorum caespitosum*, *Setaria* spp., and *Trichloris crinita.*
(b) Relationship between food availability (proportion of forage species in the field) and goat diet composition (proportion of consumed species in the diet). Forage species consumed by dry, pregnant and lactating goats in winter were: *Atriplex lampa*, *Capparis atamisquea*, *Geoffroea decorticans*, *Mimosa ephedroides*, *Prosopis flexuosa*, *Tricomaria usillo*, *Panicum urvilleanum*, *Pappophorum caespitosum*, and *Trichloris crinita.*

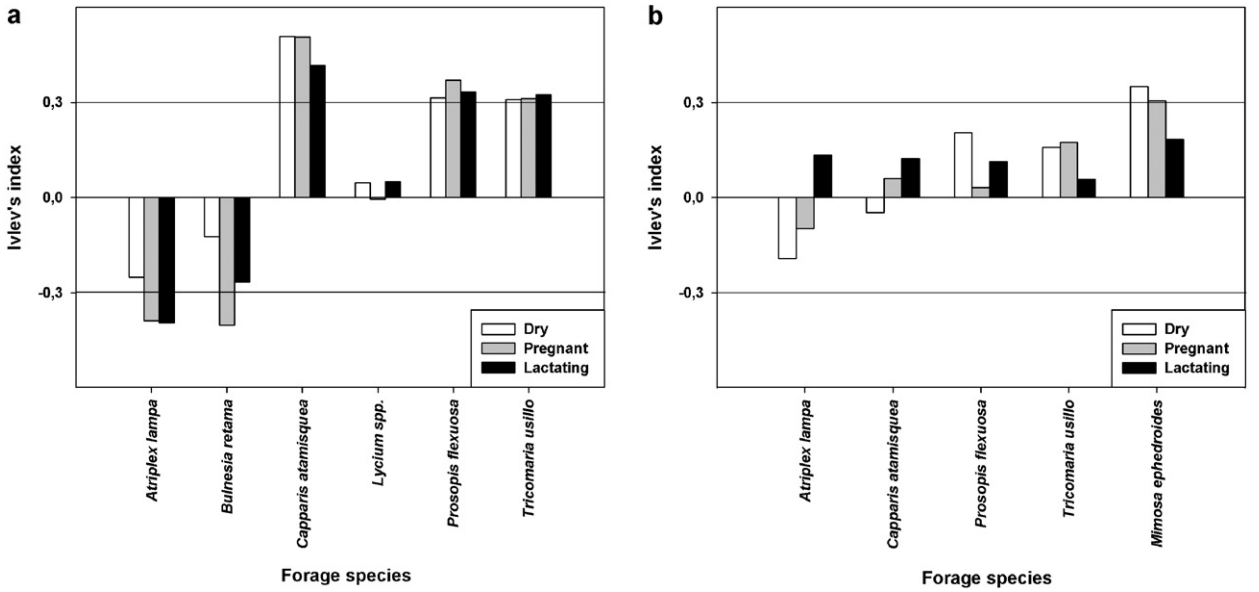

Fig. 2a. Ivlev's index of forage species consumed by dry, pregnant and lactating goats in autumn. *Atriplex lampa*; *Bulnesia retama*; *Capparis atamisquea*; *Lycium* spp.; *Prosopis flexuosa* and *Tricomaria usillo*. Forage species were classified into the following categories indicating: preference (+1.0 to +0.3), indifference (+0.3 to −0.3) and avoidance (−1.0 to −0.3).
(b) Ivlev's index of forage species consumed by dry, pregnant and lactating goats in winter. *Atriplex lampa*; *Capparis atamisquea*; *Prosopis flexuosa*; *Tricomaria usillo* and *Mimosa ephedroides*. Forage species were classified into the following categories indicating: preference (+1.0 to +0.3), indifference (+0.3 to −0.3) and avoidance (−1.0 to −0.3).

environments suggests an adaptation effort by herbivores to cope with food limitations (Kufner et al., 2008; Puig et al., 2001).

In the autumn when food availability increased, no significant correlations between diet and availability were detected for dry ($r_s = 0.51$, $p > 0.05$), pregnant or lactating goats ($r_s = 0.60$, $p > 0.05$), indicating that goats selected between available species according to their preferences. In this season, three species were preferred (*T. usillo*, *C. atamisquea* and *P. flexuosa*), and two species were avoided (*A. lampa* by pregnant and lactating goats and *B. retama* by pregnant goats). In the winter, preference was only observed for one species (*M. ephedroides*) by dry and pregnant goats, and all other species were consumed proportional to field availability (Fig. 2a and b).

Spearman's correlation analysis indicated a significant correlation in the autumn between goat preference and crude protein content for pregnant and lactating goats ($r_s = 0.6$, $p < 0.05$) and no significant correlation for dry goats ($r_s = 0.66$, $p > 0.05$). When food availability was not a limiting factor, other factors such as nutritional composition could influence the diet selection of goats. Small ruminants can modify their foraging behaviours during pregnancy and lactation (Forbes, 1993; Knubel et al., 2004; Penning et al., 1995). When foraging freely in open rangelands and able to choose food according to their energy and protein needs, goats increase the crude protein content in their diet in late pregnancy and the starch content during lactation (Fedele et al., 2002; Parsons et al., 1994). Mellado et al. (2005) reported that during advanced pregnancy or lactation, goats in the Chihuahuan desert range incorporate the forage resources that best satisfy their nutritional needs into their diets.

Although diet choice was limited, in the winter, there were significant correlations between goat preference and TP ($r_s = 0.84$, $p < 0.001$) and TT ($r_s = 0.66$, $p < 0.01$) after taking all physiological states into account. These results contradict the theory that goats minimise the intake of secondary compounds found in plants, although some authors (Alonso Díaz et al., 2007; Dziba et al., 2003) consider it an inevitable consequence of nutrient intake optimisation when availability is low.

In both seasons, Kulczynski's similarity index was high (>80) between physiological states. A great dietary overlap was observed between groups of does, coinciding with the results of Mellado et al. (2005). The selected diets included almost the same plant species in both the autumn and the winter.

4. Conclusion

Forage availability was the most important factor influencing diet selection in dry, pregnant and lactating goats in an arid environment. When food availability was not a limiting factor, goats consumed a varied diet composed of species that differed in nutrient and toxin concentrations and selected a diet that closely matched their nutritional requirements. Physiological state affected the diet selection of goats by increasing nutrient requirements, and pregnant and lactating goats preferred forage species with high protein contents.

Acknowledgments

The authors thank Juan C. Guevara for critically reviewing the manuscript and N. Horak for assisting in the English translation.

References

Alonso Díaz, M.A., Torres Acosta, J.F.J., Sandoval Castro, C.A., Hoste, H., Aguiar Caballero, A.J., Cepetillo Leal, C.M., 2007. Is goats preference of forage trees affected by their tannins or fiber content when offered in cafeteria experiments? Anim. Feed Sci. Technol. 141, 36–48.

Alvarez, J.A., Villagra, P.E., Cony, M.A., Cesca, E.M., Boninsegna, J.A., 2006. Estructura y estado de conservación de los bosques de *Prosopis flexuosa* D.C. (Fabaceae, subfamília: Mimosoideae) en el noreste de Mendoza (Argentina) (Structure and conservation status of *Prosopis flexuosa* D.C. (Fabaceae, subfamily: Mimosoideae) in the northeast of Mendoza). Rev. Chil. Hist. Nat. 79, 75–87.

Animut, G., Goetsch, A.L., 2008. Co-grazing of sheep and goats: benefits and constraints. Small Rumin. Res. 77, 127–145.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA, USA, p. 125.

Becker, K., Lohrmann, J., 1992. Feed selection by goats on tropical semi-humid rangeland. Small Rumin. Res. 8, 285–298.

Church, D.C., 1988. The Ruminant Animal: Digestive Physiology and Nutrition. Prentice-Hall, Englewood Cliffs, NJ, 564 pp.

Daget, P.H., Poissonet, J., 1971. Une méthode dïanalyse phytologique des prairies. Critéres dïapplication. Ann. Agron. 22 (1), 5–41.

Dayenoff, P., Rosati, V., Aguirre, E., Bolaño, M., 1997. Variación de la composición botánica de la dieta caprina, según el estado fenológico del pastizal natural (Changes in the botanical composition of the goat diet, according to the phenological state of the grassland). Rev. Arg. Prod. Anim. 7 (1), 117.

Distel, R.A., Villalba, J.J., 2007. Diversidad vegetal, selección de dieta y producción animal (Plant diversity, diet selection and animal production). Rev. Arg. Prod. Anim. 27, 55–63.

Dziba, L.E., Scogings, P.F., Gordon, I.J., Raats, J.G., 2003. Effects of season and breed on browse species intake rates and diet selection by goats in the False Thornveld of the Eastern Cape, South Africa. Small Rumin. Res. 47, 17–30.

Emmans, G.C., 1991. Diet selection by animals: theory and experimental design. Proc. Nutr. Soc. 50, 59–64.

Estell, R.E., 2010. Coping with shrub secondary metabolites by ruminants. Small Rumin. Res. 94, 1–9.

Fedele, V., Claps, S., Calandrelli, M., Pilla, A.M., 2002. Effect of free choice and traditional feeding systems on goat feeding behaviour and intake. Livest. Prod. Sci. 74, 19–31.

Forbes, J.M., 1986. The Voluntary Food Intake of Farm Animals. Butterworths, London.

Forbes, J.M., 1993. Physiology of regulation of food intake. In: Rook, J.A.F., Thomas, P.C. (Eds.), Nutritional Physiology of Farm Animals. Longman Press, London, pp. 177–192.

Forbes, J.M., 1995. Voluntary Feed Intake and Diet Selection in Farm Animals. CAB International, Wallingford, Oxon.

Genin, D., Pijoan, A.P., 1993. Seasonality of goat diet and plant acceptabilities in the coastal scrub of Baja California, Mexico. Small Rumin. Res. 10, 1–11.

Guevara, J.C., Bertiller, M., Estevez, O.R., Grünwaldt, E.G., Allegretti, L.I., 2006. Range and animal production in Argentina arid lands. Sècheresse 17 (1–2), 242–256.

Guevara, J.C., Grunwaldt, E.G., Estevez, O.R., Bisigato, A.J., Blanco, L.J., Biurrum, F.N., Ferrando, C.A., Chirino, C.C., Morici, E., Fernández, B., Allegretti, L.I., Passera, C.B., 2009. Range and livestock production in the Monte Desert, Argentina. J. Arid Environ. 73, 228–237.

Guevara, J.C., Allegretti, L.I., Estevez, O.R., Monge, A.S., Paez, J.A., Cony, M.A., 2010. Diets of domestic and wild herbivores grazing in common in a rangeland of Mendoza Province Argentina. In: Veress, B., Szigethy, J. (Eds.), Horizons in Earth Science Research. Nova Science Publishers, Inc, New York, pp. 463–478.

Holechek, J., Gross, B., Dabo, S.M., Stephenson, T., 1982. Effects of sample preparation, growth stage, and observer on microhistological analysis of herbivore diets. J. Wildl. Manage. 46, 502–505.

InfoStat, 2004. InfoStat Version 2004. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina.

Ivlev, V.S., 1961. Experimental Ecology of the Feeding of Fishes. Yale University Press, New Haven, Connecticut.

Knubel, B.F.R., Panter, K.E., Provenza, F.D., 2004. Pregnancy in goats does not influence intake of novel or familiar foods with or without toxins. Appl. Anim. Behav. Sci. 85, 293–305.

Kufner, M.B., Sepúlveda, L., Gavier, G., Madoery, L., Giraudo, L., 2008. Is the native deer *Mazama gouazoubira* threatened by competition of food with the exotic hare *Lepus europaeus* in the degraded Chaco in Córdoba, Argentina? J. Arid Environ. 72 (12), 2159–2167.

Launchbaugh, K.L., Provenza, F.D., Pfister, J.A., 2001. Herbivore response to anti-quality factors in forages. J. Range Manage. 54, 431–440.

Lebbie, S.H.B., 2004. Goats under household conditions. Small Rumin. Res. 51, 131–136.

Lu, C.D., 1988. Grazing behaviour and diet selection of goats. Small Rumin. Res. 3, 205–216.

Makkar, H.P.S., 2010. Quantification of Tannins in Tree and Shrub Foliage A laboratory manual. Kluwer Academic Publishers, Dordrecht.

Mellado, M., Rodriguez, A., Villarreal, J.A., Olvera, A., 2005. The effect of pregnancy and lactation on diet composition and dietary preference of goats in a desert rangeland. Small Rumin. Res. 58, 79–85.

Mellado, M., Estrada, R., Olivares, L., Pastor, F., Mellado, J., 2006. Diet selection among goats of different milk production potential on rangeland. J. Arid Environ. 66, 127–134.

Monge, A.S., 1989. Descripción de las características epidérmicas de gramíneas del centro-este de Mendoza (Ñacuñán, Santa Rosa) (Description of the epidermal characters of grasses in the east-central Mendoza, Ñacuñán, Santa Rosa). Rev. Arg. Prod. Anim. 9 (1), 57–68.

Oosting, H.J., 1956. The Study of Plant Communities. W.H. Freeman and Co., San Francisco, CA, USA.

Papachristou, T.G., Dziba, L.E., Provenza, F.D., 2005. Foraging ecology of goats and sheep on wooded rangelands. Small Rumin. Res 59 (2-3), 141–156.

Parsons, A.J., Newman, J.A., Penning, P.D., Harvey, A., Orr, R.J., 1994. Diet preference of sheep: effects of recent diet, physiological state and species abundance. J. Anim. Ecol. 63, 465–478.

Passera, C.B., Allegretti, L.I., Paez, J.A., Ibañez, G., Robles, A.B., 2004. Unidades de pastos en un sistema de producción caprina en el desierto de Mendoza, Argentina. In: García, B., García, A., Vazquez de Aldana, B.R., Zabalgogeazcoa, I. (Eds.), Pastos y Ganadería Extensiva. Salamanca, pp. 745–750.

Passera, C.B., Allegretti, L.I., Robles, A.B., 2007. Effect of non-prescribed fire on *Atriplex lampa* community composition, in the Guadal plateau of Mendoza province, Argentina. Arid Land Res. Manage. 21, 91–105.

Penning, P., Parsons, A., Orr, R., Harvey, A., Champion, R., 1995. Intake and behaviour responses by sheep, in different physiological states, when grazing monocultures of grass or white clover. Appl. Anim. Behav. Sci. 45, 63–78.

Provenza, F.D., Villalba, J.J., Dziba, L.E., Atwood, S.B., Banner, R.E., 2003. Linking herbivore experience, varied diets, and plant biochemical diversity. Small Rumin. Res. 49, 257–274.

Puig, S., Videla, F., Cona, M.I., Monge, A.S., 2001. Use of food availability by guanacos (*Lama guanicoe*) and livestock in Northern Patagonia (Mendoza, Argentina). J. Arid Environ. 47, 291–308.

Ramírez-Orduña, R., Ramírez, R.G., Romero-Vadillo, E., González-Rodríguez, H., Armenta-Quintana, J.A., Avalos-Castro, R., 2008. Diet and nutrition of range goats on a sarcocaulescent shrubland from Baja California Sur, Mexico. Small Rumin. Res. 76, 166–176.

Rogosic, J., Estell, R., Ivankovic, S., Kezic, J., Razov, J., 2008. Potential mechanisms to increase shrub intake and performance of small ruminants in mediterranean shrubby ecosystems. Small Rumin. Res. 74, 1–15.

Silanikove, N., 2000. The physiological basis of adaptation in goats to harsh environments. Small Rumin. Res. 35, 181–193.

Sparks, D.R., Malechek, J.C., 1968. Estimating percentage dry weight in diets using a microscopic technique. J. Range Manage. 21 (4), 264–265.

Steel, R.G., Torrie, J.H., 1980. Principles and Procedures of Statistics, 2nd ed. McGraw-Hill, New York, NY, 633 pp.

Van den Bosch, S., Guevara, J.C., Tacchini, F.M., Estevez, O.R., 1997. Nutrient content of browse species in the arid rangelands of the Mendoza plain, Argentina. J. Arid Environ. 37, 285–298.

Villagra, P.E., Villalba, R., Boninsegna, J.A., 2005. Structure and growth rate of *Prosopis flexuosa* woodlands in two contrasting environments of the central Monte desert. J. Arid Environ. 60, 197–199.