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Ruminal degradation synchrony of crude protein and organic matter of forage species, as a preference determinant in free-range goats in the Sonoran Desert of Baja California Sur

Sincronía de la degradación ruminal de proteína cruda y materia orgánica de especies forrajeras como determinante de preferencia en cabras de libre pastoreo en el desierto sonorense de Baja California Sur

Rafael Ramírez-Orduña[1*]✉, José Ángel Armenta-Quintana[1], Juan Manuel Ramírez-Orduña[1]✉ and Raúl Avalos-Castro[2]✉

[1] Departamento de Ciencia Animal y Conservación del hábitat. Universidad Autónoma de Baja California Sur. Apartado Postal 676. La Paz Baja California Sur. 2300. México.

[2] Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias (INIFAP). CIRNO-C.E. Todos Santos. La Paz, Baja California Sur.

ABSTRACT

The objective of the study was to evaluate the relationship between the preference index (IP) and synchrony (IS) of forage species from Baja California Sur. Samples of the 23 forage species of trees and shrubs were obtained to perform in situ digestibility analyzes using four Creole-Nubian goats. Collections were carried out in winter and spring of 2004, and summer and autumn of 2005. The extent of degradation per hour and total of 24 h was calculated from the amount of OM and PC degraded per hour; these data were used to calculate the IS. The seasonal PI data set was obtained from previously published information. A logistic regression model was used to explain the probability of occurrence of the IP with the IS. The regression model to explain the IP from the IS was significant and predictive for six species, being positive for *Adelia virgata*, *Amaratus palmeri*, *Haematoxilon brasiletto*, *Lippia palmeri* and *Prosopis sp.*, and negative for *Bursera microphyla*. For other tree species and legumes in general, the model was significant, but not predictive, therefore, it is necessary to include other factors to fit the model.

Keywords: range goats; arid zones; synchrony index; preference index; forage intake**.**

RESUMEN

El objetivo del estudio fue evaluar la relación existente entre el índice de preferencia (IP) y sincronía (IS) de especies forrajeras de Baja California Sur. Se obtuvieron muestras de las 23 especies forrajeras de árboles y arbustos para realizar análisis de digestibilidad *in situ* utilizando para ello cuatro cabras con encaste de criollas-Nubio. Se llevaron a cabo colecciones en invierno y primavera del 2004 y verano y otoño de 2005. La extensión de degradación por hora y total de 24 h se calculó a partir de la cantidad de MO y PC degradados por hora; estos datos se utilizaron para calcular el IS. El conjunto de datos del IP estacional se obtuvo de información publicada previamente. Se utilizó un modelo de regresión logística para explicar la probabilidad de ocurrencia del IP con el IS. El modelo de regresión para explicar el IP a partir del IS fue significativo y predictivo para seis especies, siendo positiva para *Adelia virgata*, *Amaratus palmeri*, *Haematoxilon brasiletto*, *Lippia palmeri* y *Prosopis sp.*, y negativa para *Bursera microphyla*. Para otras especies arbóreas y las leguminosas en general, el modelo fue significativo, pero no predictivo, por lo tanto, es necesaria incluir otros factores para ajustar el modelo.

Palabras clave: cabras de agostadero; zonas aridas; índice de sincronización; índice de preferencia; consumo de forraje

INTRODUCTION

In harsh environments, the nutritional quality of pasture grazed by goats range from poor to medium quality (Mellado *et al*., 1991; Landau *et al*., 2000; Juarez *et al*., 2004; Chebli *et al*., 2021; Chebli *et al*., 2022), and its nutritional quality does not fall considerably during the dry season (Rutagwenda *et al*., 1989; Kababya *et al*., 1998; Ramirez-Orduña *et al*., 2008; Chebli *et al*., 2021; Chebli *et al*., 2022). The main advantage of desert goats over goats from temperate areas while digesting medium quality roughage, may relate to their ability to maintain higher microbial density on the particulate matter, hence a higher total ruminal fermentation rate and higher volatile fatty acids formation (Silanikove, 1996; Silanikove *et al*., 1993) which was related to their superior urea recycling capacity whereas digest diet below 8 % dietary protein concentration (Maltz *et al*., 1981; Silanikove *et al*., 1980; Silanikove, 1984). However, between 8 and 20 % dietary protein concentration, urea excretion is a function of protein intake with no special retention mechanism (Silanikove, 2000), but goats consuming diets in this range of protein concentration still depend on microbial efficiency to digest forage diet.

Some results with goats grazing the rangelands of the Sonoran Desert at Baja California Sur, Mexico, showed higher selection of browse legumes and cacti species at the end of spring, and higher selection over non-legumes and forbs during late summer, autumn and winter, although legume and non-legume trees and shrubs accounted for at least 50 % of goats diet all around the year. This selection resulted in a constant diet in truly digestible crude CP (11 ± 0.4 %) and metabolizable energy (2.4 ± 0.1 megacalories (Mcal)•kg^{-1}) throughout the year (Ramirez-Orduña *et al*., 2008). Other

*Author for correspondence: Rafael Ramirez Orduña
e-mail: rramirez@uabcs.mx
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results in a similar area suggest that goats select diets with a high synchrony index (≥ 0.7) between organic matter (OM) and crude protein (CP) degradation (Armenta-Quintana *et al*., 2011), presumably to maintain good ruminal fermentation, microbial protein synthesis and feed utilization (Chumoawadee *et al*., 2006). However, it is not clear whether goats prefer forage species because they have intrinsically high IS in the rumen, or whether they select complementary species for a high IS diet. The objective of this study was to evaluate the relationship between the preference index (PI) of 23 forage species and their SI.

MATERIALS AND METHODS

The study was carried out at the "Palmar de Abajo" ranch within a 200 hectares (ha) rangeland and a stocking rate of 0.13 to 0.36 heads/ha, located in Baja California Sur, Mexico, at 23° 38´ 40´´ North latitude and 110° 18´ 07´´ West longitude and a 200 m above sea level elevation. Vegetation is considered as a sarcoculescent shrubland, composed mainly (92 %) of shrubs from 1 to 3 m, and trees from 4 to 10 m in height, and about 23 % of these are endemic species (León de Luz y Coria, 1992; Wiggins, 1980). The study area is in a subtropical zone characterized by a very dry and warm weather (BWhw. Köppen system), with an annual precipitation of about 182 mm occurring mainly from july through september (80 %), however some rainfall may occur in winter (INEGI, 2001), annual mean temperature is of 21.2 ºC and the soil is alkaline, regosol, eutric, calcareous and very permeable (INEGI, 2001).

About 2.5 to 6 kg of tree-boughs and shrubs were obtained and sun dried to obtain about 100 g of dry leave and twig samples of the following forage plants: *Adelia virgata*, *Amaranthus palmeri*, *Antigonon leptopus*, *Caesalpinia pannosa*, *Calliandra californica*, *Fouquieria diguetii*, *Haematoxylon brasiletto*, *Hymenoclea monogyra*, *Jatrohpa cinérea*, *Lysium torreyi*, *Ruellia peninsularis*, *Sapium biloculare* and *Solanum hindsianum*. Samples were dried in a forced air oven at 55°C for 72 h, ground to pass a 1mm screen in a Wiley mill to reduce all plant fragments to a uniform size. Two subsamples were taken and stored in plastic containers for *in situ* digestibility analyses. Samplings were carried out in winter (9-13 december) and spring (29 april to 5 may) of 2004, and summer (20-24 august) and autumn (24-28 november) of 2005.

Four range Creole-Nubio goats fitted with a ruminal cannula (37.1± 1.35 kg body weight), were used to estimate the rate and extent of OM and CP loss of each plant species sample at each sampling date. The animals were fed with *Medicago sativa* (14 % CP) twice a day (8:00 and 18:00 h) and had free access to water. About 3 g of DM of each plant species sample were placed into nylon bags (5 x 10 cm and 50 µm pore size). Duplicated nylon bags containing feed samples were incubated in the ventral sac of the rumen of each goat at designated time points (1, 2, 3, 4, 8, 12, 24, 48, 72 and 100 h) and retrieved together at once. After incubation, bags were washed together through five 1-minute cold rinse cycles in a domestic washing machine and a final rinse in tap water. Zero-time (washing losses) was estimated by soaking unincubated three bags per sample in warm tap water at 39 °C for 20 min. After washing, bags and content were dried in an oven at 55°C for 48 h and reweighed. Residual samples were analyzed for OM and CP (AOAC, 2000). The *in-situ* digestibility (ISD) of OM and CP of each incubation time was calculated with the equation: *ISD* (%) = *[(Initial weight – final weight)/Initial weight]/ 100*.

The parameters of ruminal digestion of OM and CP were calculated by fitted the *ISD* data set to the equation (Ørskov and McDonald, 1979) $P = a+b(1-exp^{-kd•t})$, where *P* is the cumulative amount degraded of OM or CP at time *t* (hours), *a* is the soluble fraction of the sample that is lost during washing, *b* is the insoluble fraction that is potentially degraded in the rumen and *kd* is the constant rate of degradation of the fraction *b*.

Additional data set of seasonal degradation kinetic parameters of forage species from the same rangelands were obtained from previous works (Ramirez-Orduña *et al*., 2003a; 2003b), this data set include the species *Acacia peninsularis*, *Cercidium floridum*, *Mimosa xanti*, *Pithecellobium confine*, *Prosopis sp*., *Bursera microphylla*, *Cyrtocarpa edulis*, *Lippia palmeri*, *Opuntia cholla* and *Turnera diffusa*. Kinetic parameters of digestion characterize the intrinsic properties of feeds that limit their availability to ruminants, and can be used to simulate aspects of the forage to understand the digestion processes (Mertens, 1996).

From the two data set, the hourly and total (24 h) effective degradation (ED) of the OM (EDOM) and CP (EDCP) was calculated using the equation $ED= a + \{[(b•kd)/(kd+kp)] [1-exp^{(kd+kp)•t}]\}$ (Ørskov and McDonald, 1970), where *kp* represents the fractional passage rate from the rumen. The EDOM and EDCP were estimated using a passage rate of 5 %/h (*kp* = 0.05). The hourly EDOM and EDCP for each sample were calculated as the difference among degraded material at successive hours. From the calculated hourly EDOM and EDCP, a synchrony index (SI) of OM to CP degradation was calculated as described by Sinclair *et al*. (2000), with $SI = \{25- Σ1\text{-}24\ (\sqrt{[(25\text{-hourly } N/OM)^2]})/24\}/25$, where 25 = 25 g of N/kg of OM truly digested in the rumen, which is assumed to be the optimal ratio (Czerkawski. 1986). A synchrony index of 1.0 represents perfect synchrony between OM and CP release throughout digestion time and values less than 1.0 indicate the degree of asynchrony.

Seasonal data set of preference index for the individual 23 species was obtained from published information (Ramirez-Orduña *et al*., 2008; Armenta-Quintana *et al*., 2011). For both data set, preference index (PI) of goats for plant species were established with the arithmetic range by the quotient of the percent of each plant species in diet, and the percentage of each plant species in the study area according to the Ivlev´s selectivity index (Strauss, 1979) PI = Fi – Hi / Fi + Hi, were Fi = percent forage consumed by the animal of a species, Hi = total percentage of forage available for one specie. An index of +1.0 indicates that the specie was preferred, 0 indicate that the specie was preferred according to its availability, and -1.0 indicates that the specie was rejected by goats.

For the care of animals and procedures, the Official Mexican Standard NOM-062-ZOO-1999 for the care of animals was considered, as well as the law for the protection of domestic animals for Baja California Sur and the recommendations of the Ethics and Animal Welfare Committee of the Autonomous University of Baja California Sur.

Data of effective degradation and synchrony index of OM and CP degradation were subjected to analysis of variance with sampling date as the main effect. Means were separated using Tukey´s test. Considering a maximum of 50 % of available forage, PI values used were dichotomized to develop a binary logistic regression model to explain the probability of occurrence preference with the SI as independent variable. PI values higher than -0.33 were codified as 1 and lower values were codified as cero, in accordance with Stuth (1991). The ROA´s statistical efficiency and the Hosmer and Lemeshow procedures were used to know the goodness of fit of the model. All tests were performed with alpha ≤ 0.05 (SPSS 2011).

RESULTS AND DISCUSSION

Results about EDOM and EDCP of the thirteen studied species are shown in Table 1, seasonal means of SI of this species and additional calculated data for another ten plant species are shown in Table 2. Calculated PI by season for each 23 species are shown in Table 3 and results of binary logistic regression between SI and PI by plant species, season and plant type are shown in table 4.

Acacia peninsularis, *Adelia virgata*, *Amaranthus palmeri*, *Haematoxylon brasiletto*, *Lippia palmeri* and *Prosopis sp.,* had a significant and positive relation between PI and SI (Table 4). *Acacia* species are known to be an important protein source in many area around the world, showing CP content from 12 to 18 % on DM basis depending on area, stage of growth and aridity (Ben Salem *et al*., 2002; Mousa, 2011; Soltan *et al*., 2012; Ngambu *et al*., 2013; Quiroz-Cardoso *et al*., 2015; Mabeza *et al*., 2017). Accordingly, *Acacia peninsularis* is an endemic specie from Baja California Sur, Mexico, containing 11 to 15% CP throughout the year; moreover, *Acacia peninsularis* EDOM and EDCP were no different between seasons (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b). In this study the calculated mean SI was high and constant throughout the year (Table 2). According to the calculated results, this specie was preferred nearest their availability all year (Table 3). Logistic regression analyses were highly significant indicating a 6.7 increase in the probability of preference when SI increase, however, even when the R^2 was high, the highly significance of the Hosmer and Lemeshow Chi^2 procedure indicate a lack of fit of the model and that other factors should be considered to explain the preference of this plant (Table 4). The presence of phenolic compounds in *Acacia* species has a negative effect on their nutritional value and intake by livestock (Degen *et al*., 1998). Similarly, tannins have been attributed as one of the major causes of their limited use as a livestock fodder (Makkar, 1993; Kumar and D'Mello, 1995). From 2 - 4 % tannins in the diet protects protein from rumen degradation and increases the absorption of essential amino acids, whereas 4 - 10% depresses voluntary feed intake, reduce palatability and decrease digestibility, inhibit digestive enzymes and could be toxic to rumen micro-organisms (Ku-

Tabla 1. Contenido de materia orgánica (% de MS), proteína bruta (% de MS) y características de degradación efectiva (%) en especies vegetales seleccionadas por cabras pastoreando en un matorral sarcocaulescente de Baja California Sur, México.

Table 1. Content of organic matter (% of DM), crude protein (% of DM) and effective degradation characteristics (%), in plant species selected by ranging goats grazing on a sarcocaulescent shrubland of Baja California Sur, Mexico.

Plant Specie	OM	Effective degradation of OM				CP	Effective degradation of CP			
	Anual Mean	Spring	Summer	Fall	Winter	Anual Mean	Spring	Summer	Fall	Winter
Adelia virgata	91.8	81.1^{a}	78.3^{b}	80.5^{ab}	80.2^{ab}	11.3	77.2^{ab}	79.3^{a}	76.0^{b}	78.1^{ab}
Amaranthus palmeri	81.0	54.1^{b}	53.3^{b}	63.3^{a}	51.9^{b}	10.6	80.9^{a}	71.3^{c}	75.9^{b}	75.6^{b}
Antigonon leptopus	87.8	61.3^{a}	54.8^{ab}	54.7^{ab}	51.5^{b}	14.5	51.8^{b}	58.6^{a}	48.7^{b}	51.7^{b}
Caesalpinia pannosa	91.8	77.2^{bc}	80.7^{a}	75.3^{c}	79.2^{ab}	11.3	29.6^{b}	51.7^{a}	27.8^{b}	30.0^{b}
Calliandra californica	92.5	43.3^{b}	54.0^{a}	41.9^{b}	43.6^{b}	10.3	81.4^{a}	81.5^{a}	83.8^{a}	70.3^{b}
Fouquieria diguetii	89.0	60.2^{ab}	66.1^{a}	48.4^{c}	56.1^{b}	4.9	40.1^{a}	29.9^{a}	17.4^{b}	12.9^{b}
Haematoxylon brasiletto	91.2	62.4^{b}	66.0^{a}	52.6^{c}	61.0^{b}	8.6	47.0^{b}	64.5^{a}	42.0^{c}	44.3^{bc}
Hymenoclea monogyra	87.8	72.2^{a}	71.4^{a}	66.0^{b}	69.8^{ab}	15.8	79.6^{a}	74.2^{b}	56.7^{d}	66.4^{c}
Jatropha cinerea	83.0	76.9^{a}	69.4^{b}	72.2^{b}	72.4^{b}	14.7	80.3^{a}	67.4^{b}	80.1^{a}	78.6^{a}
Lysium torreyi	68.2	72.5^{b}	78.8^{a}	68.5^{b}	69.5^{b}	11.1	81.8^{a}	77.5^{b}	76.7^{b}	73.6^{b}
Ruellia peninsularis	81.0	61.7^{b}	71.4^{a}	64.4^{b}	64.2^{b}	9.0	72.6^{a}	73.7^{a}	63.3^{b}	58.8^{b}
Sapium biloculare	91.9	80.4^{b}	82.6^{ab}	84.5^{a}	83.5^{ab}	9.3	70.4^{c}	80.5^{ab}	80.9^{a}	75.1^{bc}
Solanum hindsianum	90.5	55.0^{a}	47.7^{b}	56.2^{a}	51.8^{b}	12.8	82.4^{b}	83.5^{a}	78.1^{c}	72.7^{d}

$^{a, b, c, d}$ Different literals within rows are statistically different (P < 0.05).

Tabla 2. Índice de sincronía calculado entre la degradación de la materia orgánica y la proteína cruda en especies vegetales seleccionadas por cabras pastoreando sobre un matorral sarcocaulescente de Baja California Sur, México.
Table 2. Calculated synchrony index between the degradation of organic matter and crude protein, in plant species selected by ranging goats grazing on a sarcocaulescent rangeland from Baja California Sur, Mexico.

Plant Specie	Synchrony Index				Annual Mean	Standard Deviation
	Spring	Summer	Fall	Winter		
Acacia peninsularis	0.73[a]	0.79[a]	0.79[a]	0.78[a]	0.77	0.07
Adelia virgata	0.66[a]	0.65[a]	0.71[a]	0.69[a]	0.68	0.04
Amaranthus palmeri	0.92[b]	0.97[a]	0.80[d]	0.88[c]	0.87	0.06
Antigonon leptopus	0.84[b]	0.91[a]	0.83[b]	0.75[c]	0.83	0.06
Bursera microphyla	0.69[ab]	0.46[b]	0.70[a]	0.83[a]	0.67	0.25
Caesalpinia pannosa	0.60[b]	0.08[c]	0.89[a]	0.22[c]	0.45	0.34
Calliandra californica	0.96[a]	0.31[b]	0.90[ab]	0.90[ab]	0.83	0.31
Cercidium floridum	0.80[ab]	0.75[b]	0.86[a]	0.81[ab]	0.80	0.09
Cirtocarpa edulis	0.73[b]	0.88[a]	0.91[a]	0.87[a]	0.85	0.12
Fouquieria diguetii	0.82[a]	0.84[a]	0.24[b]	0.95[a]	0.74	0.28
Haematoxylon brasiletto	0.70[ab]	0.44[ab]	0.93[a]	0.10[b]	0.65	0.44
Hymenoclea monogyra	0.83[a]	0.75[b]	0.74[bc]	0.67[c]	0.75	0.07
Jatropha cinerea	0.80[d]	0.96[a]	0.84[c]	0.89[b]	0.87	0.06
Lippia palmeri	0.77[a]	0.74[a]	0.74[a]	0.77[a]	0.76	0.14
Lysium torreyi	0.79[a]	0.64[a]	0.75[a]	0.81[a]	0.74	0.11
Mimosa xantii	0.82[a]	0.76[a]	0.84[a]	0.84[a]	0.81	0.11
Opuntia cholla	0.79[a]	0.77[a]	0.83[a]	0.84[a]	0.81	0.11
Pitecellobium confine	0.79[a]	0.80[a]	0.87[a]	0.85[a]	0.83	0.11
Prosopis sp.	0.73[a]	0.73[a]	0.74[a]	0.73[a]	0.73	0.10
Ruellia peninsularis	0.74[a]	0.82[a]	0.82[a]	0.63[b]	0.75	0.09
Sapium biloculare	0.63[ab]	0.82[a]	0.29[b]	0.51[ab]	0.58	0.28
Solanum hindsianum	0.66[ab]	0.79[a]	0.29[b]	0.63[ab]	0.59	0.27
Turnera difusa	0.60[a]	0.66[a]	0.74[a]	0.74[a]	0.69	0.18
Mean	0.75[ab]	0.73[b]	0.78[a]	0.77[a]	0.76	0.19
Standar Deviation	0.13	0.22	0.23	0.18		

[a, b, c] Different literals within rows are statistically different ($P < 0.05$)

mar and Vaithiyanathan, 1990; Terrill *et al*., 1992; Barry and McNabb, 1999). *Acacia peninsularis* was found to contain 6.8 to 7.6 % condensed tannins (Ramírez-Orduña *et al*., 2003b).

Information about *Adelia virgata* and *Amaranthus palmeri* as a fodder for goats is scarse. *Adelia virgata* had a lower EDOM in summer but lower EDCP in fall (Table 1), however had a medium to high SI throughout the year (Table 2). The analyzed data about preference by goats indicate no statistical difference between seasons (Table 3). The logistic regression model indicates that an increase in SI determines significatively an increase in the probability of preference by 8.3 times (Table 4). On the other hand, *Amaranthus palmeri* had lower EDCP in summer but higher EDOM in fall (Table 1), with high SI values all year with seasonal differences, being higher in summer (Table 2), however was highly preferred in spring (Table 3). For this plant, an SI increase increased significatively almost 20 times the preference, and the variance explained by SI was significant, being a good predictor of PI (Table 4).

During fall, *Haematoxylon brasiletto* had a lower EDOM and EDCP (Table 1), but a higher SI and PI (Table 2 and 3 respectively), therefore the logistic regression was significant indicating that an increase in SI determine an increase of 16.4 times in the probability of preference, in this case the Hosmer

Tabla 3. Índice de preferencia (PI) y valor dicotomizado (DV) de especies de plantas seleccionadas por cabras pastoreando sobre un matorral sarcocaulescente de Baja California Sur, México.
Table 3. Preference index (PI) and dichotomized value (DV) of plant species, selected by ranging goats grazing on a sarcocaulescent rangeland from Baja California Sur, Mexico.

Plant Specie	Spring		Summer		Fall		Winter	
	PI	DV	PI	DV	PI	DV	PI	DV
Acacia peninsularis	0.07[a]	1	0.21[a]	1	-0.18[a]	1	-0.15[a]	1
Adelia virgata	0.10[a]	1	0.39[a]	1	0.25[a]	1	0.16[a]	1
Amaranthus palmeri	1.0[a]	1	0.39[ab]	1	0.10[b]	1	0.53[ab]	1
Antigonon leptopus	-0.02[a]	1	-0.15[a]	1	-0.55[a]	0	-0.01[a]	1
Bursera microphyla	-1.0[b]	0	-0.62[a]	0	-1.0[b]	0	-0.85[b]	0
Caesalpinia pannosa	-0.89[a]	0	-1.0[a]	0	-1.0[a]	0	-0.93[a]	0
Calliandra californica	-0.24[a]	1	-0.95[b]	0	-0.96[b]	0	-0.72[b]	0
Cercidium floridum	-0.12[a]	1	-0.80[b]	0	-0.56[b]	0	-0.14[a]	1
Cirtocarpa edulis	-0.86[c]	0	-0.39[b]	0	-0.10[a]	1	-0.93[c]	0
Fouquieria diguetii	-0.57[ab]	0	-0.39[a]	0	-0.85[b]	0	-0.43[a]	0
Haematoxylon brasiletto	-0.15[a]	1	-0.15[a]	1	0.02[a]	1	-0.23[a]	1
Hymenoclea monogyra	-0.46[a]	0	-0.35[a]	0	-0.40[a]	0	-0.07[a]	1
Jatropha cinerea	-0.77[b]	0	-0.84[b]	0	-0.72[ab]	0	-0.53[a]	0
Lippia palmeri	-1.0[c]	0	-0.26[b]	1	-0.07[b]	1	0.74[a]	1
Lysium torreyi	-0.39[a]	0	-0.13[a]	1	-0.19[a]	1	-0.30[a]	1
Mimosa xantii	0.0[ab]	1	-0.76[c]	0	0.22[a]	1	-0.28[b]	1
Opuntia cholla	-0.17[a]	1	-0.61[b]	0	-0.16[a]	1	-0.39[ab]	0
Pithecellobium confine	0.07[a]	1	-0.94[b]	0	-0.15[a]	1	0.10[a]	1
Prosopis sp.	-0.25[a]	1	-0.34[a]	0	-0.27[a]	1	-0.25[a]	1
Ruellia peninsularis	-1.0[b]	0	-0.35[a]	0	-0.34[a]	0	-0.65[ab]	0
Sapium biloculare	-0.50[a]	0	-0.75[b]	0	-0.71[ab]	0	-1.0[c]	0
Solanum hindsianum	-0.56[a]	0	-0.06[a]	1	-0.04[a]	1	-0.31[a]	1
Turnera difusa	-1.0[a]	0	-1.0[a]	0	-0.76[a]	0	-0.69[a]	0

[a, b, c] Different literals within rows are statistically different ($P < 0.05$).

and Lemeshow was not significant indicating a high model goodness fit (Table 4). *Lippia palmeri* EDOM and EDCP was lower in spring and summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), however their SI was high and constant throughout the year (Table 2), but was most preferred in fall (Table 3). There was a significative relation between SI and PI, however the R^2 of the logistic regression was low, but the Hosmer and Lemeshow results indicate an acceptable goodness of fit, and the model indicates that an increase in SI determines an increase in the probability of preference by almost three times (Table 4).

Prosopis sp., had a constant EDOM, EDPC (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b) and SI throughout the year (Table 2), with a constant high SI but negative PI, indicating that the preference of this specie is low or tend to be rejected, overall in summer (Table 3), however there was a significative relation between SI and PI, and even when the R^2 of the logistic model was low, the Hosmer and Lemeshow results were no significant indicating that an increase in SI determines an increase in the probability of preference by 3 times within an acceptable goodness of fit (Table 4).

Conversely to previous results, *Bursera microphyla*, *Cyrtocarpa edulis* and *Fouqieria diguetii* had a negatively significant relation between PI and SI. *Bursera microphyla* is a specie with a higher EDOM and EDCP during spring (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b) but lower SI (Table 2), and its PI was higher during summer (Table 3), therefore the logistic regression analyses between SI and PI were negative and highly significant, and the goodness of fit of the model was high (Table 4).

Cyrtocarpa edulis had a lower EDOM and EDCP in spring and summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), their SI was lower during spring, but the SI values were over 0.70 all year (Table 2). This specie seems to be most preferred in fall (Table 3), logistic regression analy-

Tabla 4. Análisis de regresión logística para explicar el índice de preferencia a partir del índice de sincronía entre la degradación de materia orgánica y proteína cruda para especies vegetales, época y tipo de planta seleccionadas por cabras pastoreando en un matorral de Baja California Sur, México.
Table 4. Logistic regression analyses to explain the preference index, from the synchrony index, between the degradation of organic matter and crude protein for plant species, season and plant type selected by goats ranging on a shrubland from Baja California Sur, Mexico.

Main effect	ROA (Chi^2)	Goodness of Fit[1]		Model summary					
		R^2	Chi^2	B	TE	Wald	Odd Ratio (OR)	Confidence Interval 9 5% for OR	
								Lower	Higher
Plant specie									
Acacia peninsularis	20.3***	0.46	31.6***	1.9	0.5	15.7***	6.7	2.6	17.2
Adelia virgata	6.5**	0.45	6.3^{ns}	2.1	0.9	5.1*	8.3	1.3	52.2
Amaranthus palmeri	11.5***	0.78	11.1^{ns}	3.0	1.3	5.6*	19.8	1.7	233.2
Antigonon leptopus	2.2^{ns}	0.17	10.6^{ns}	0.9	0.6	2.1^{ns}	2.5	0.7	9.0
Bursera microphyla	47.3***	0.85	9.6^{ns}	-4.7	1.2	14.6***	0.0	0.0	0.1
Caesalpinia pannosa	2.8^{ns}	0.28	12.1^{ns}	-1.1	0.7	2.4^{ns}	0.3	0.1	1.3
Cercidium floridum	3.2^{ns}	0.09	11.3^{ns}	-0.6	0.4	3.1^{ns}	0.5	0.3	1.1
Cyrtocarpa edulis	10.1**	0.25	15.2*	-1.1	0.4	8.9**	0.3	0.2	0.7
Fouquieria diguetii	11.7***	0.75	16.1*	-2.8	1.2	6.1*	0.1	0.0	0.6
Haematoxylon brasiletto	7.1**	0.68	4.5^{ns}	2.8	1.4	4.1*	16.4	1.1	248.2
Hymenoclea monogyra	1.3^{ns}	0.10	6.6^{ns}	-0.8	0.7	1.2^{ns}	0.5	0.1	1.8
Lippia palmeri	6.8**	0.18	10.8^{ns}	1.0	0.4	6.3*	2.8	1.2	6.2
Lysium torreyi	0.0^{ns}	0.00	3.6^{ns}	0.1	0.7	0.0^{ns}	1.1	0.3	4.4
Mimosa xantii	3.5^{ns}	0.09	15.0*	0.7	0.4	3.3^{ns}	1.9	1.0	4.0
Opuntia cholla	0.4^{ns}	0.01	18.2*	-0.2	0.4	0.4^{ns}	0.8	0.4	1.6
Pithecellobium confine	0.5^{ns}	0.01	20.0**	0.3	0.3	0.5^{ns}	1.3	0.6	2.5
Prosopis sp	7.1**	0.18	8.6^{ns}	1.1	0.4	6.5*	3.0	1.3	6.8
Ruellia peninsularis	3.6^{ns}	0.27	7.4^{ns}	-1.4	0.8	3.2^{ns}	0.3	0.1	1.1
Solanum hindsianum	0.0^{ns}	0.00	1.6^{ns}	0.1	0.8	0.0^{ns}	1.1	0.3	5.2
Season									
Winter	0.64^{ns}	0.00	23.4**	-0.15	0.19	0.64^{ns}	0.85	0.58	1.2
Spring	0.16^{ns}	0.00	20.7**	-0.08	0.20	0.16^{ns}	0.92	0.62	1.3
Summer	21.8***	0.17	6.0^{ns}	-1.0	0.22	20.0***	0.36	0.23	0.5
Fall	0.01^{ns}	0.00	5.7^{ns}	0.02	0.19	0.01^{ns}	1.02	0.70	1.4
Plant type									
Non-leguminous	36.1***	0.11	8.8^{ns}	-0.8	0.13	34.2***	0.4	0.34	0.5
Leguminous	7.3**	0.03	20.2**	0.4	0.15	7.2**	1.5	1.11	2.0

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, ns: not significant. [1] Negelkerke R^2 and Hosmer and Lemeshow Chi^2.

ses were significant but the relation between SI and PI was negative and the R^2 was low, and the procedure of Hosmer and Lemeshow was significant indicating a lack of fit of the model, thus other factors should be considered (Table 4). Similarly, *Fouqieria diguetii* has a lower EDOM and EDCP (Table 1), SI (Table 2) and PI (Table 3) even when ROA analyses and Wald value were significant and the Nagelkerke R^2 was high, the Hosmer and Lemeshow procedure was significant indicating a lack of fit in the relation between SI and PI and therefore, other factors could help explain the preference of this specie (Table 4).

For ten species there were no relation between PI and SI. *Antigonon leptopus* had a lower EDOM in winter and higher EDCP (Table 1) and SI in summer, it was less preferred mostly in fall (Table 3) even when this plant had a high SI through the year (Table 2). *Caesalpina pannosa* had a higher EDOM and EDCP during summer (Table 1), however in this season had lower SI (Table 2), it was refused rather than preferred all the year (Table 3) and animals preferred it in a very small amount during winter and spring, therefore a reasonable dichotomizing process and logistic regression analysis was not possible. *Cercidium floridum* EDOM and EDCP was low during summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), also had a lower SI in this season (Table

2) when was less preferred (Table 3). *Hymenoclea monogyra* EDOM and EDPC was high in spring (Table 1) but was more preferred in winter (Table 3), consequently there was no relationship between SI and PI (Table 4). *Lysium torreyi* EDOM was higher in summer but EDCP was higher in spring (Table 1); even when the SI was high and constant in all seasons (table 2) this specie was more preferred during summer and fall (Table 3), therefore the logistic regression indicates no relation between SI and PI (Table 4). *Mimosa xantii* had a constant EDOM in all seasons but EDCP was lower in summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), however in this season its SI was not affected significantly (Table 2) but was less preferred (Table 3), and there was not a relation between SI and PI (Table 4).

Previous local data indicated that *Opuntia cholla* EDOM was constant between seasons, but their EDCP was lower in summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), therefore in this study their calculated SI was high and constant all year (Table 2) but was less preferred during summer (Table 3). *Phitecellobium confine* preference was higher during winter and spring (Table 3), in this seasons EDOM was higher but EDCP (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b) and SI (Table 2) did not change during the year, hence there was no relation between SI and PI (Table 4). *Ruellia peninsularis* had a higher EDOM in summer and higher EDCP in spring and summer (Table 1) but was rejected practically during spring (Table 3), however its SI was high through the year with a significant reduction during winter (Table 4). *Solanum hindsianum* had a lower EDOM in summer and winter and high EDCP in summer (Table 1), however it had a lower SI in fall (Table 2) and its PI was coded 0 in spring (Table 3), therefore there was no a relation between SI and PI (Table 4).

Calliandra californica had a higher EDOM during summer but lower EDCP during winter (Table 1), however this specie had a higher SI during spring (Table 2), and it was most preferred in this season (Table 3). *Jatropha cinerea* had a higher EDOM in spring but during summer had lower EDCP (Table 1), PI (Table 3) and higher SI (Table 2), animals preferred it in a very small amount all year, therefore for these species a reasonable dichotomizing process and logistic regression analysis was not possible. Similarly, *Sapium biloculare* had a lower EDOM and EDCP (Table 1) but was most preferred during spring (Table 3), also had a lower SI during fall (Table 2), nevertheless, no dichotomizing process and logistic regression analyses was possible. In the summer, *Turnera diffusa* EDOM was lower than in spring and EDCP was lower in spring and summer (Ramirez-Orduña *et al*., 2003a; Ramirez-Orduña *et al*., 2003b), It had a SI without significant variation all year (Table 2), but this specie was less preferred in fall and winter or was rejected in spring and summer (Table 3); therefore, a logistic regression analysis was not possible.

Total data analyses of logistic regression showed a significant relation between SI and PI (ROA $P < 0.01$), there was a lack of fit of the model ($R^2 = 0.015$, Hosmer and Lemeshow $P < 0.05$). In addition, the model suggests a negative relation between PI and SI (OR = 0.76, Wald 7.5, $P < 0.01$). Seasonal analyses of data were not significant, except for the summer ($P < 0.001$) where the model showed a goodness of fit and predictive value ($R^2 = 0.17$, Hosmer and Lemeshow $P > 0.05$), however, the relation was negative (OR = 0.36, Wald 20, $P < 0.001$).

Ramírez-Orduña *et al*. (2008) found that during summer, autumn and winter, diets of goats were composed mainly of non-legumes trees and shrubs such as *Adelia virgata*, *Manguifera indica*, *Jatropha cinerea*, *Lissium torreyi* and *Fouquieria diguetii*, followed by forbs, legumes and cacti, and that dietary NDF was lowest in late spring and summer. Nonstructural carbohydrates content was highest in spring and late summer, CP was lowest during spring and early summer, similar responses to those reported by Ramírez-Orduña *et al*. (2003a) in five legumes browsed by range goats, where low CP, low NDF and high non-structural carbohydrates (NSC) in spring and summer were related to higher consumption of fruits of cacti, and fruits and flowers of legumes trees and shrubs, such diet characteristics suggests an asynchronous diet.

In accordance with these results, plant type analyses show a significant relation between SI and PI (Table 4). This relation was inverse for non-legumes but direct for legumes species, nevertheless for legumes the model was not predictive ($R^2 = 0.3$, Hosmer and Lemeshow $P < 0.01$). Legumes species are higher in CP and degraded protein than non-legumes in spring and summer (Ramirez-Orduña *et al*., 20003), these results indicate that legumes may be preferred in accordance with their synchrony of degradation characteristics and that other factors such as secondary compounds may be more important in determine the preference of this plant type.

CONCLUSIONS

According to our results, goats may prefer a few forage species or plant type because their high synchrony of OM and CP availability in the rumen. However, some other plant species or type shown an inverse relationship, therefore, goats may select complementary plant species or type throughout the year to obtain a diet with high synchrony index, additionally, it appears that other factors may affect the preference in more determinant form than the ruminal availability of CP and OM, mainly in legumes species and during the dry season.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest regarding this manuscript.

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