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LA CONCIENCIA DEL DATO

LA BIODIVERSIDAD: HISTORIA Y CONTEXTO DE UN CONCEPTO

HETEROGENEIDAD ESTRUCTURAL Y LUMÍNICA DEL SOTOBOSQUE
DE UNA SELVA NUBLADA ANDINA DE VENEZUELA



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COVER

Jorge Seguí, Argentina, 1945
 Riding clouds, undated
 121 x 121 x 20 cm
 Mural relief, bronze, polychrome iron

Seguí presents his figures in a frontal manner, as if in a painting, making it almost unnecessary to move around them. The volume and space

construction makes reference to the absurd, or to the imaginary, such as happens with the New Figurative paintings, a tendency in which Seguí has remained active.

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SEASONAL DYNAMICS OF RUMINAL CRUDE PROTEIN DIGESTION

BROWSE SPECIES FROM BAJA CALIFORNIA SUR, MEXICO

Rafael Ramírez-Orduña, Roque G. Ramírez-Lozano, Marco V. Gómez-Meza,
Juan A. Armenta-Quintana, Juan M. Ramírez-Orduña, Ramón Cepeda-Palacios
y Juan M. Ávila-Sandoval

SUMMARY

Ten native browse species from Baja California Sur, Mexico, were nutritionally evaluated in each season of three consecutive years measuring crude protein (CP), protein fraction in neutral detergent fiber (NDIP) and in acid detergent fiber (ADIP), and the extent of crude protein degradability. Five legumes and five non-legumes were collected from 16 linear 30m transects. All plants in each transect were identified and measured to estimate Shannon's diversity index, species richness, aerial cover and relative frequency, dominance, density and importance. *Medicago sativa L.* hay was used as reference forage with high nutritional quality. To estimate the effective degradability of crude protein (EDCP), duplicate nylon bags (10x15cm; 50µm pore size) containing 4g of each plant species from each season

and year were incubated in the ventral part of the rumen in four cannulated beef steers. In general, CP content, NDIP, ADIP and EDCP were significantly higher in legumes. Neutral detergent soluble CP was higher in non-legumes during spring and summer, and CP and EDCP were higher in autumn. Legume EDCP was significantly lower in summer, possibly due to reduction of available cell wall protein. Only shrubs such as *Opuntia cholla*, *Prosopis* sp. and *Cercidium floridum* had EDCP values comparable to or higher than alfalfa hay. *Cyrtocarpa edulis* had the lowest EDCP. Legume CP was more degraded in the rumen than that of non-legumes. A high quality forage period in autumn and winter, and a low quality one in spring and summer, could be distinguished.

RESUMEN

Diez arbustos nativos de Baja California Sur, México, fueron nutricionalmente evaluados en cada estación durante tres años consecutivos, midiendo proteína cruda (PC), fracción proteica en la fibra detergente neutro (FPDN) y en la fibra detergente ácido (FPDA), y velocidad y grado de degradabilidad de PC. Cinco leguminosas y cinco no-leguminosas fueron colectadas de 16 transectos lineales de 30m. Todas las plantas de cada transecto fueron identificadas y medidas para estimar el índice de diversidad Shannon, riqueza de las especies, cobertura aérea y frecuencia relativa, dominancia, densidad e importancia. Heno de *Medicago sativa L.* fue usado como forraje de referencia de alta calidad nutritiva. Para estimar la degradabilidad efectiva de PC (DEPC), se usaron por duplicado bolsas nylon (10x15cm; poro de 50µm) conteniendo 4g de cada especie de cada estación y año,

incubadas en la parte ventral del rumen de cuatro becerros de carne canulados. En general, el contenido de PC, FPDN, FPDA y DEPC fueron significativamente mayores en leguminosas. La PC soluble en la fibra detergente neutro fue mayor en las no-leguminosas en primavera y verano, y PC y DEPC fueron mayores en otoño. La DEPC en leguminosas fue significativamente menor en verano, posiblemente por reducción en la proteína disponible de la pared celular. Solo especies como *Opuntia cholla*, *Prosopis* sp. y *Cercidium floridum* tuvieron valores de DEPC comparables o mayores a la alfalfa. *Cyrtocarpa edulis* tuvo la menor DEPC. La PC de leguminosas fue más degradada en el rumen que las no-leguminosas. Se distinguen dos períodos de calidad nutritiva, uno de alta calidad en otoño e invierno y otro de baja en primavera y verano.

Introduction

The State of Baja California Sur, in Northern Mexico, is considered as an extremely arid zone (COTECOCA, 1975). Of the vegetation, 92% is mainly composed by

shrubs 1-3m in height. Most farmers are traditional small holders. However, the use of shrubs as food resources for livestock has been mostly supported by farmer's experience and the knowledge that some shrubs are palatable for

animals (Arriaga and Cancino, 1992).

Many browse plants that grow in Northeastern Mexico have been used as fodder for ruminants, especially legume species (Ramírez, 1996). In other arid and semiarid regions

of the world, the use of browse species has been promoted due to severe food shortages, harsh and prolonged drought periods, low animal performance, mortality and uneconomic production (Devendra, 1990). However, the low quality and sea-

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RESUMO

dez arbustos nativos da Baixa Califórnia Sul, México, foram nutricionalmente avaliados em cada estação durante três anos consecutivos, medindo proteína crua (PC), fração protéica insolúvel detergente neutro (FPDN) e na fibra detergente ácido (ADIP), e velocidade e grau de degradabilidade de PC. Cinco leguminosas e cinco não leguminosas foram coletadas de 16 transects lineares de 30 m. Todas as plantas de cada transecto foram identificadas e medidas para estimar o índice de diversidade de Shannon, riqueza das espécies, cobertura aérea e frequência relativa, dominância, densidade e importância. Feno de *Medicago sativa L.* foi usado como forragem de referência de alta qualidade nutritiva. Para estimar a degradabilidade efetiva de PC (DEPC), se usaram pôr duplamente sacolas nylon (10 x 15 cm, poro de 50 µm) contendo 4 g de cada espécie de cada estação e ano, incubadas na parte ventral do rúmen de quatro bezerros de carne canulados. Em geral, o conteúdo de PC, FPDN, FPDA e DEPC foram significativamente maiores em leguminosas. A PC solúvel na fibra detergente neutro foi maior nas não leguminosas na primavera e no verão, e PC e DEPC foram maiores no outono. A DEPC em leguminosas foi significativamente menor no verão, possivelmente por redução na proteína disponível da parede celular. Somente espécies como *Opuntia cholla*, *Prosopis sp.* e *Cercidium floridum* tiveram valores de DEPC comparáveis ou maiores à alfafa. *Cyrtocarpa edulis* teve a menor DEPC. A PC de leguminosas foi mais degradada no rúmen que as não leguminosas. Distinguem-se dois períodos de qualidade nutritiva, um de alta qualidade no outono e no inverno e outro de baixa na primavera e no verão.

real nature of the forage supply, together with low intake by animals and poor digestibility of forage, are the main factors contributing to the low productivity of ruminants feeding on browse species (Remenyi and McWilliams, 1986).

In ruminants, where feed is fermented in the rumen, this fermentation has confounded the prediction of animal performance from dietary ingredients. Therefore, a mechanistic understanding of fermentation is needed for sustained development of animal production. Mechanistic models require quantitative estimates of carbohydrates and protein digestion (Satter, 1980; Russell *et al.*, 1992; Sniffen *et al.*, 1992).

The object of this study was to evaluate and compare, seasonally, during three consecutive years, the crude protein content (CP), the CP composition of the cell wall, and the rate and extent of CP digestion in leaves of five legumes and five non-legumes growing in a shrubland from Baja California Sur, Mexico. *Medicago sativa* hay was included as reference forage of high nutritional quality.

Materials and Methods

Site and collection area

This study was conducted in the *Palmar de Abajo* ranch (800ha), located in La Paz, Baja California Sur, Mexico, at 23°38'40"N and

110°18'07"W. The climate of the region is arid with annual mean temperature of 21.2°C. Rainfall is generally present during the summer (July, August and September) and winter (January and February) seasons. Total year rainfall during the study period was 177, 47 and 61.7mm for 1993, 1994 and 1995, respectively. The soils are mainly of alkaline, regosol, eutric and calcareous types, which are very permeable (Flores, 1998).

Branches from the legumes *Acacia peninsularis* (Brit. L. Rose) Standley; *Cercidium floridum* (Benth); *Mimosa xantii*, Gray; *Pithecellobium confine* (Standley) and *Prosopis sp.* (Torr) and the non-legumes *Bursera microphylla* Gray (Burceraceae); *Cyrtocarpa edulis* (Brand) Stand (Anacardiaceae); *Lippia palmeri*, S. Wats (Verbenaceae); *Opuntia cholla*, Weber (Cactaceae) and *Turnera diffusa* Wild (Turneraceae) were collected from 16 randomly located linear transects of 30m long. These browse species are reported to be consumed selectively by cattle and goats in Baja California Sur (Arriaga and Cancino, 1992). Collections were carried out during winter (February 23), spring (May 23), summer (August 23) and autumn (November 23), in 1993, 1994 and 1995. Branches of each species were bulked in triplicate samples for each season and year, and were allowed to

dry under shade. Leaves were removed manually, oven dried (45°C) for 72h, ground in a Willey mill (1mm). Alfalfa hay (*Medicago sativa L.*) obtained from a commercial store was considered as reference forage. Within each transect the species were identified and individuals from each species were counted. The length of intercepts occupied by individuals touching the transect were recorded. The Shannon diversity index (Shannon, 1948) and the species richness index (Hart, 1985) were determined.

Chemical and in situ digestibility analyses

Duplicate samples were subjected to chemical analysis

$$ISDCP\% = \frac{(Initial\ weight - final\ weight)}{Initial\ weight} \times 100$$

to determine crude protein (CP; AOAC, 1980), neutral detergent insoluble protein (NDIP) and acid detergent insoluble protein (ADIP; Van Soest *et al.*, 1991). ADIP is considered insoluble protein (Pichard and Van Soest, 1977) because it is associated with lignin, tannin and Maillard compounds (Krishnamoorthy *et al.*, 1982). Insoluble protein in neutral detergent but soluble in acid detergent was calculated as NDIP-ADIP (Goering and Van Soest, 1970; Krishnamoorthy *et al.*, 1982).

The nylon bag technique was used to estimate the rate (kd, %/h) and extent of CP loss (%). Nylon bags of 10x15cm and 50µm pore size containing 4g of each plant species were incubated in the ventral part of the rumen of 4 cannulated beef steers (250 ± 5.3kg body weight). During the trial steers were fed alfalfa hay *ad libitum* (16% CP). Duplicate nylon bags were incubated in each steer for 1, 2, 3, 4, 8, 12, 24, 48, 72 and 100 hours. Zero-time disappearance was determined from non-incubated bags. After incubation, the bags were dried at 60°C in an oven for 48h. The *in situ* disappearance of crude protein (ISDCP) for every period of incubation was calculated as

To estimate the non-linear characteristics of CP, *in situ* disappearance values from nylon bags, in each incubation period were used in the following equation (Ørskov and McDonald, 1979)

$$p = a + b(1-e^{-kt})$$

where p: percentage of disappearance of the CP at time t, a: soluble fraction of CP that is lost during washing, b: insoluble fraction of CP that is degraded in the rumen, kd: constant rate of disappearance of fraction b, and t: incubation time.

The non-linear parameters a , b and kd and effective degradability of the CP ($EDCP = \frac{(a+b)kd}{(kd+kp)}[e^{-(kd+kp)t}]$), where kp : outflow rate from the rumen and T : lag time (period in h that rumen microbes take to initiate fermentation), were all calculated using the Neway program (McDonald, 1981). The EDCP values of browse species and *M. sativa* hay were estimated using a rumen outflow rate of 2%/h.

Statistical analysis

Data of CP, CP fractions in the cell wall, degradation rate of CP and EDCP were analyzed using a general lineal models procedure (SPSS, 1999). Mean values of legumes and non-legumes species were compared using orthogonal contrasts. The season and year effect for each plant type (legumes and non-legumes) was determined by a two way analysis of variance model. Values of acid detergent lignin (ADL) and condensed tannins (CT) reported by Ramírez-Orduña *et al.* (2003) were used to estimate simple linear correlation coefficients between ADL, CP and EDCP, NDIP, ADIP.

Results and Discussion

The Shannon diversity index of the study area was 1.0 %, species richness was 10.62% and the total aerial cover was 62.05%. Of the legume species, *Prosopis* sp. and *M. xantii* were the most and least important species, whereas among the non-legumes *O. cholla* was the most important species, and *L. palmeri* and *T. diffusa* were the least important species (Table I). In the different seasons (Table II), legumes and non-legumes covered roughly the same area (about 10%). Non-legumes contributed almost twice in importance value than legumes in all seasons because of their higher relative frequency, density and dominance; however, both plant types were similar in all

TABLE I
CONTRIBUTION (%) OF FIVE LEGUME AND FIVE NON-LEGUME SPECIES TO THE BOTANICAL STRUCTURE OF A RANGELAND FROM BAJA CALIFORNIA SUR, MEXICO

Species	Aerial cover	Relative frequency	Relative density	Relative dominance	Importance value
Legumes					
<i>Prosopis</i> sp	5.54	22.63	3.64	8.62	11.63
<i>Pithecellobium confine</i>	1.40	18.88	1.25	2.22	7.45
<i>Cercidium floridum</i>	0.97	16.69	1.05	1.53	6.42
<i>Acacia peninsularis</i>	1.01	15.53	1.15	1.66	6.11
<i>Mimosa xantii</i>	0.19	6.42	0.36	0.34	2.37
Non legumes					
<i>Opuntia cholla</i>	5.50	66.29	13.09	8.77	29.38
<i>Bursera microphylla</i>	3.73	47.24	4.45	6.23	19.30
<i>Cyrtocarpa edulis</i>	3.44	41.43	2.85	5.35	16.54
<i>Lippia palmeri</i>	0.15	9.72	0.60	0.25	3.52
<i>Turnera diffusa</i>	0.06	8.68	0.45	0.10	3.08

TABLE II
SEASONAL CONTRIBUTION (%) OF LEGUME AND NON-LEGUME SPECIES TO THE BOTANICAL STRUCTURE OF A RANGELAND FROM BAJA CALIFORNIA SUR, MEXICO

Plant type	Season	Aerial cover	Relative frequency	Relative density	Relative dominance	Importance value
Legumes	Winter	9.7	62.3	5.8	15.1	27.7
	Spring	10.1	48.4	5.3	14.0	22.5
	Summer	5.9	44.8	4.6	11.1	20.1
	Autumn	10.1	52.7	8.4	16.6	25.9
Non legumes	Winter	13.5	84.3	21.8	21.4	42.5
	Spring	16.3	83.6	22.6	22.6	42.9
	Summer	10.4	86.0	19.3	19.6	41.6
	Autumn	10.7	90.0	19.3	18.2	42.5

seasons with respect to covered area. Non-legumes decreased all these variables from winter to autumn, whereas legumes were lower in summer and higher in autumn than other seasons.

Chemical composition

The year was the principal factor affecting EDCP, soluble and slowly degraded fractions, whereas the interaction year x plant type affected mainly the

NDIP-ADIP content in plants. Moreover, plant type was the main factor that affected the CP, NDIP, ADIP and CP degradation rate (Table III).

The shrub *O. cholla* (6.0 ± 2.8 annual mean ± standard

TABLE III
F VALUES AND SIGNIFICANCE LEVELS RESULTED FROM THE MULTIPLE FACTORIAL ANALYSIS OF VARIANCE

Effect	CP	NDIP	ADIP	NDIP-ADIP	Soluble fraction	Degradeable fraction	Degradation rate of CP	EDCP
Year	5.3**	9.8***	11.6***	2.3ns	92.7***	33.3***	6.6**	63.5***
Season	16.0***	9.4***	30.9***	1.6ns	14.8***	3.7*	2.3ns	24.0***
Plant type	331.4***	35.6***	72.7***	0.8ns	27.7***	6.2*	12.1**	28.2***
Year x season	14.5***	3.5**	4.6***	2.5*	11.6***	14.2***	1.2ns	3.3**
Year x plant type	0.1ns	1.1ns	1.0ns	11.6***	3.7*	6.2**	0.7ns	3.6*
Season x plant type	1.7ns	7.5***	17.1***	1.4ns	4.0**	3.5*	0.8ns	9.2***
Year x season x plant type	1.4ns	0.3ns	0.5ns	1.5ns	1.4ns	1.2ns	2.4*	2.8**

*** (P<0.001), **(P<0.01), *(P<0.05), ns:= not significant.

TABLE IV
SEASONAL CHANGES OF THE ANNUAL MEANS (THREE YEARS) OF CRUDE PROTEIN (CP, % DM),
NEUTRAL DETERGENT INSOLUBLE PROTEIN (NDIP, % CP) AND ACID DETERGENT
INSOLUBLE PROTEIN (ADIP, % CP) CONTENT IN NATIVE LEGUMES AND NON-LEGUMES
FROM BAJA CALIFORNIA SUR, MEXICO

Plants	CP				NDIP				ADIP			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
<i>Medicago sativa</i>	15.6	17.7	15.6	15.6	14.4	12.0	15.7	14.4	6.6	5.3	5.3	6.6
<i>Acacia peninsularis</i>	13.8	10.8	11.5	13.9	35.5	29.6	30.8	30.7	16.1	21.5	22.3	18.7
<i>Cercidium floridum</i>	17.1	12.4	13.8	16.8	28.1	33.6	28.4	28.3	16.3	13.0	15.7	11.1
<i>Mimosa xanti</i>	14.4	11.6	17.9	16.2	25.8	30.3	21.6	23.9	16.4	22.1	13.8	14.6
<i>Pithecellobium confine</i>	19.6	15.8	14.7	17.5	30.2	29.3	29.9	33.8	15.0	23.1	23.7	19.3
<i>Prosopis</i> sp.	21.4	18.6	17.6	20.0	23.8	20.4	18.9	20.4	7.4	7.2	8.7	7.2
Legumes	17.3 ^a	13.8 ^c	15.1 ^b	16.9 ^{ab}	28.7 ^a	28.6 ^a	25.9 ^a	27.4 ^a	14.2 ^a	17.4 ^a	16.9 ^a	14.2 ^a
<i>Bursera microphylla</i>	9.2	7.5	9.5	9.6	26.0	59.3	26.4	27.7	19.7	51.0	24.6	19.1
<i>Cyrtocarpa edulis</i>	11.6	10.6	10.4	15.1	34.5	44.6	46.8	25.4	15.5	32.2	26.4	13.4
<i>Lippia palmeri</i>	9.3	4.8	7.5	11.2	44.7	53.6	53.3	32.8	28.3	49.7	27.3	17.6
<i>Opuntia cholla</i>	5.1	4.3	7.5	7.2	30.5	32.1	23.9	27.8	14.9	21.3	16.3	11.2
<i>Turnera difusa</i>	8.9	5.9	8.9	10.2	29.0	35.5	29.8	25.1	16.9	40.4	28.8	17.8
Non Legumes	8.8 ^b	6.6 ^c	8.9 ^b	10.7 ^a	32.9 ^{bc}	45.0 ^a	34.8 ^b	27.8 ^c	19.1 ^{bc}	38.9 ^a	24.5 ^b	15.8 ^c
Effect of plant type												
Significant level ¹	***	***	***	***	ns	***	**	ns	*	***	**	ns
Standard error	1.0	0.8	0.8	0.8	2.5	3.0	2.9	1.8	2.1	2.8	2.3	2.4
Seasonal means	13.0 ^{ab}	10.2 ^c	12.1 ^b	13.8 ^a	30.8 ^b	36.8 ^a	30.2 ^b	27.6 ^b	16.6 ^a	28.1 ^c	20.5 ^b	15.0 ^a
Effect of year	1993	1994	1995		1993	1994	1995		1993	1994	1995	
Legumes	16.0 ^a	15.0 ^a	16.3 ^a		23.0 ^c	31.9 ^a	28.1 ^b		15.5 ^b	18.4 ^a	13.1 ^b	
Non Legumes	9.0 ^{ab}	7.8 ^b	9.4 ^a		33.3 ^a	38.1 ^a	34.3 ^a		22.6 ^b	28.9 ^a	22.5 ^b	
Annual means	12.5 ^a	11.5 ^b	12.8 ^a		28.1 ^c	34.9 ^a	31.2 ^b		19.0 ^b	23.5 ^a	17.8 ^b	

* means in rows with different letter superscripts differ ($P<0.05$).

¹comparison was made using orthogonal contrasts between legumes and non-legumes.

***($P<0.001$); **($P<0.01$); ns: not significant.

error) had the lowest CP content (Table IV) while *Prosopis* sp. had the highest (19.4 ± 3.4), even higher than alfalfa hay (16.1 ± 2.7). Legume species were significantly higher in CP (15.8 ± 3.9) than non-legumes (8.7 ± 3.5). In autumn, non-legumes had a higher CP content, and in legumes it was higher in winter. The CP values for alfalfa hay were comparable to those values reported for alfalfa hay mid bloom (16.5% DM) by Sniffen *et al.* (1992). Only non-legume species were significantly affected by the year; in years when rainfall was lower, the CP in non-legumes was also lower (7.7 to 4%).

According to Sniffen *et al.* (1992) NDIP is the fraction that includes both available and unavailable proteins linked to cell wall. Legumes (27.7 ± 8.0) had lower NDIP

(%CP) than non-legumes (35.1 ± 13.6). Non-legumes had the higher NDIP content during spring and summer; but legumes were not significantly affected by season (Table IV). NDIP in legumes was significantly higher in 1994 than in 1993 and 1995, and in alfalfa hay it was lower (14.1 ± 5.9) than in all the shrubs evaluated in this study. *L. palmeri* had the highest (45.4 ± 15.4) and *Prosopis* sp. the lowest NDIP values. According to Sniffen *et al.* (1992) this fraction includes both buffer soluble proteins that are rapidly degraded and buffer insoluble, but neutral, detergent soluble proteins that are intermediately degraded and may be degraded in the rumen depending on the relative rates of degradation and passage. This means that the CP proportion of native legume that could be

rapidly to intermediately degraded in the rumen species remains high throughout the year and is higher than in non-legumes. However, in non-legumes this fraction might be reduced in spring and summer. Also, CP in cell content of alfalfa hay (85.8 ± 5.9), evaluated in this study, had a higher proportion of total CP as compared to all browse species, and was intermediate to the corresponding values (74.8 and 92.1% CP) reported for mid bloom alfalfa hay by Sniffen *et al.* (1992) and Elizalde *et al.* (1999a), respectively. Evidence from numerous feeding studies indicate that excessive ruminal protein degradation could be the most limiting nutritional factor in higher quality temperate legume forages such as alfalfa hay (Broderick, 1995).

The ADIP (% CP) content in legume species (15.7 ± 6.9)

was significantly lower than in non-legumes (24.6 ± 13.6). Moreover, ADIP in non-legumes was higher during spring and summer seasons, whereas ADIP in legumes was not affected by season. However, with exception of autumn, there were significant differences among seasons between legumes and non-legumes (Table IV). Legumes and non-legumes increased significantly ($P<0.05$) their ADIP in 1994. Alfalfa hay (6.0 ± 1.7) had the lowest ADIP concentration. This fraction is the unavailable protein bound to lignin, tannin-protein complexes or Maillard products. Therefore, this fraction is highly resistant to ruminal and mammalian enzymes activity (Krishnamoorthy *et al.*, 1983) and it would not provide aminoacids post ruminally (Krishnamoorthy *et al.*, 1982).

During the summer months (Table V), legumes signifi-

TABLE V
**SEASONAL DYNAMICS OF ANNUAL MEANS (THREE YEARS) OF CELL WALL AVAILABLE PROTEIN
 (NDIP-ADIP; % CP), SOLUBLE CRUDE PROTEIN (% DM) AND DEGRADABLE PROTEIN (% DM) CONTENT IN
 NATIVE LEGUMES AND NON-LEGUMES FROM BAJA CALIFORNIA SUR, MEXICO**

Plants	Cell wall available protein				Soluble crude protein				Degradable protein			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
<i>Medicago sativa</i>	7.7	6.6	10.3	7.7	47.1	46.7	51.2	51.9	43.9	31.7	40.6	43.0
<i>Acacia peninsularis</i>	19.4	8.0	8.4	11.9	34.5	40.7	38.8	41.8	50.4	45.7	56.1	42.2
<i>Cercidium floridum</i>	11.8	20.6	12.6	17.1	43.6	39.8	38.0	52.2	41.4	52.8	48.5	45.5
<i>Mimosa xantii</i>	9.3	8.2	7.7	9.2	48.1	44.0	45.3	50.3	40.2	42.3	28.7	39.4
<i>Pithecellobium confine</i>	15.2	6.1	6.2	14.5	42.5	42.9	44.4	47.1	21.7	44.3	31.4	35.1
<i>Prosopis</i> sp.	16.3	13.1	10.1	13.2	60.4	61.4	65.7	65.7	30.4	25.9	22.4	23.3
Legumes	14.4 ^a	11.2 ^{ab}	9.0 ^b	13.2 ^a	45.8 ^b	45.7 ^b	46.5 ^b	51.4 ^a	36.8 ^a	42.2 ^a	37.4 ^a	37.1 ^a
<i>Bursera microphylla</i>	6.3	11.4	5.0	8.5	44.2	25.9	46.5	48.4	38.3	33.7	29.7	30.1
<i>Cyrtocarpa edulis</i>	19.0	12.4	20.4	11.9	21.9	31.2	32.5	43.7	70.9	52.8	60.4	47.3
<i>Lippia palmeri</i>	16.3	19.0	25.9	15.2	35.5	32.5	23.8	45.3	45.4	54.3	32.5	40.0
<i>Opuntia cholla</i>	15.5	10.8	7.5	16.6	57.8	57.5	42.7	69.6	32.0	34.8	47.4	20.5
<i>Turnera diffusa</i>	12.1	5.0	5.4	7.3	42.5	39.5	23.3	47.9	49.8	38.9	49.2	33.0
Non Legumes	13.8 ^a	12.4 ^a	13.0 ^a	11.9 ^a	40.4 ^b	37.3 ^{bc}	34.5 ^c	51.0 ^a	47.3 ^a	42.9 ^a	44.6 ^a	34.2 ^b
Effect of plant type												
Significant level ¹	ns	ns	ns	ns	*	***	***	ns	**	ns	*	ns
Standard error	1.7	2.4	2.7	2.0	2.5	2.4	2.9	2.4	3.3	3.1	4.0	2.6
Seasonal means	14.1 ^a	11.7 ^{ab}	10.8 ^b	12.5 ^{ab}	43.1 ^b	41.5 ^b	40.7 ^b	51.2 ^a	42.0 ^a	42.6 ^a	40.9 ^a	35.6 ^b
Effect of year	1993	1994	1995		1993	1994	1995		1993	1994	1995	
Legumes	7.4 ^b	13.4 ^a	15.0 ^a		38.1 ^c	47.0 ^b	56.9 ^a		47.0 ^a	33.5 ^b	34.7 ^b	
Non Legumes	14.9 ^a	10.6 ^b	12.9 ^{ab}		31.1 ^c	36.8 ^b	54.6 ^a		51.8 ^a	43.6 ^b	31.3 ^c	
Annual means	10.9 ^b	12.1 ^{ab}	14.0 ^a		34.6 ^c	42.0 ^b	55.8 ^a		49.4 ^a	38.4 ^b	33.0 ^c	

* Means in rows with different letter superscripts differ ($P < 0.05$).

¹ comparison was made using orthogonal contrasts between legumes and non-legumes

***($P < 0.001$), **($P < 0.01$), * ($P < 0.05$), ns: not significant.

cantly reduced the NDIP-ADIP (%CP), which also showed a significant year effect, increasing in 1994 (13.4 ± 0.9) and 1995 (15.0 ± 1.0), three years of lowest precipitation. On the other hand, non-legumes were neither different among seasons nor among years. Non-legumes such as *B. microphylla* (7.9 ± 7.6), *M. xantii* (8.6 ± 4.9), and *T. diffusa* (8.1 ± 5.8) had comparable NDIP-ADIP contents to those of alfalfa hay (8.1 ± 4.9). *L. palmeri* had with the highest value (18.4 ± 13.2).

The available protein in cell wall (NDIP-ADIP) is considered as slowly degraded in the rumen, for being in the cell wall (Van Soest *et al.*, 1981; Krishnamoorthy *et al.*, 1983), and their extent of degradation depends on the degradation and passage rates of the fibrous fraction (Sniffen *et al.*, 1992). It appears that if the

passage rate is very fast or the degradation rate is very slow, then this fraction would escape degradation in the rumen. The NDIP-ADIP values for alfalfa hay in this study are comparable to the values reported by Elizalde *et al.* (1999a) and Sniffen *et al.* (1992), of 7.8 and 11.2% CP, respectively.

Degradoability of crude protein

In non-legumes, the soluble fraction (a) increased in autumn, after the rainy season, but was similar in the other seasons. (Table V). With exception of autumn, legumes were higher in this fraction than non-legumes. Legumes were similar to alfalfa hay, however the values obtained for the latter were higher than those values reported by Elizalde *et al.* (1999b) for mid vegetative (40.2%) to late flowering (41.3%) alfalfa hay,

but were similar to the results of Hoffman *et al.* (1993) for late bud (44.8%) to midbloom (48.2%) alfalfa hay.

The slowly degraded fraction (b) was similar among seasons in legume species. In non-legumes, however, this fraction was significantly lower during winter, when the soluble fraction was highest. During winter and summer fraction (a) was higher in legumes than in non-legumes; however both plant types were affected by the year (Table V). Legumes in this study had a lower slowly degraded fraction than alfalfa hay in all seasons except in spring. Alfalfa hay values were lower than those reported by Elizalde *et al.* (1999b) for mid vegetative (53.5%) to late flowering (47.1%) alfalfa hay, but were similar to the results of Hoffman *et al.* (1993) for late bud (41.1%) to midbloom (30.8%) alfalfa hay.

Only during the autumn months, legumes had significantly lower CP degradation rates than non-legumes species (Table VI). The CP of *Prosopis* sp., *B. microphylla* and *O. cholla* was rapidly degraded; however, *A. peninsularis*, *C. edulis*, *M. xantii* and *P. confine* were slowly degraded in rumen of cattle. The CP of alfalfa hay was degraded faster than all native shrubs evaluated in this study. High NDSP values (Table II) in alfalfa would have positively influenced the CP degradation rate in rumen of cattle. Conversely, low NDSP in browse plants would have reduced the digestion rate of CP.

Only during the spring and summer seasons, legumes had EDCP significantly higher values than non-legumes. Species such as *O. cholla*, *Prosopis* sp. and *C. floridum* had the highest EDCP values and were comparable to those in

TABLE VI
SEASONAL VARIATION OF ANNUAL MEANS (THREE YEARS) OF CRUDE PROTEIN DEGRADATION RATE (%/HOUR) AND EFFECTIVE DEGRADABILITY OF CRUDE PROTEIN (%) IN NATIVE LEGUMES AND NON-LEGUMES FROM BAJA CALIFORNIA SUR, MEXICO

Plants	CP degradation rate				CP effective degradability			
	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
<i>Medicago sativa</i>	11.3	16.9	14.5	11.7	74.4	64.2	74.0	76.8
<i>Acacia peninsularis</i>	4.2	3.8	2.7	3.4	62.3	63.2	60.6	64.5
<i>Cercidium floridum</i>	6.2	8.0	10.1	5.0	67.7	71.8	55.5	78.0
<i>Mimosa xanti</i>	6.1	2.6	2.1	1.8	64.1	63.1	58.6	65.0
<i>Pithecellobium confine</i>	13.2	3.0	1.7	2.0	55.8	56.3	54.3	57.5
<i>Prosopis</i> sp.	10.4	15.7	8.2	10.1	78.8	75.9	80.0	81.7
Legumes	8.0 ^a	6.6 ^{ab}	5.0 ^{ab}	4.5 ^b	65.7 ^{ab}	66.1 ^{ab}	61.8 ^b	69.3 ^a
<i>Bursera microphylla</i>	10.9	12.8	14.2	13.4	66.5	40.7	64.1	66.0
<i>Crotoncarpa edulis</i>	3.8	0.5	0.2	2.9	57.3	41.3	38.7	60.5
<i>Lippia palmeri</i>	18.9	9.1	10.0	10.4	59.8	44.2	38.8	68.8
<i>Opuntia cholla</i>	13.2	8.4	8.1	8.9	76.1	77.5	58.3	82.1
<i>Turnera diffusa</i>	7.4	11.2	6.0	14.2	71.7	58.2	41.3	66.1
Non Legumes	10.8 ^a	8.4 ^a	7.5 ^a	9.9 ^a	66.3 ^a	52.4 ^b	48.9 ^b	68.7 ^a
Effect of plant type								
Significant level ¹	ns	ns	ns	***	ns	***	**	ns
Standard error	0.02	0.02	0.02	.01	2.6	3.0	3.7	2.5
Overall seasonal means	9.4 ^a	7.5 ^{ab}	6.2 ^b	7.2 ^{ab}	66.0 ^a	59.2 ^b	55.6 ^b	69.0 ^a
Effect of year	1993	1994	1995		1993	1994	1995	
Legumes	3.7 ^b	8.5 ^a	5.8 ^b		56.9 ^c	64.1 ^b	76.1 ^a	
Non Legumes	8.3 ^{ab}	11.5 ^a	7.8 ^b		54.4 ^b	54.1 ^b	68.9 ^a	
Annual means	6.0 ^b	10.0 ^a	6.8 ^b		55.7 ^c	59.2 ^b	72.5 ^a	

* means in a row with different letter superscripts differ ($P<0.05$).

¹ comparison was made using orthogonal contrasts between legumes and non-legumes.

**($P<0.001$), **($P<.01$), ns: not significant.

alfalfa hay. *C. edulis* and *L. palmeri* had the lowest values (Table VI). The EDCP values for alfalfa hay obtained in this study are comparable to those reported by Elizalde *et al.* (1999b) and Hoffman *et al.* (1993) of 72.9 and 72.1%, respectively. In this study, browse plants had higher EDCP values during 1995 than other years, and were also higher in autumn and winter than in other seasons.

Ramírez *et al.* (2000a,b) and Moya-Rodríguez *et al.* (2002) reported that lignin content and condensed tannins negatively influenced the EDCP in leaves of 22 browse species growing in Northeastern Mexico. They also found that during the winter months the EDCP was higher than in other seasons. They concluded that in some situations, because of warm temperatures and wet climate that occurred at the end of winter, native

shrubs from Northeastern Mexico could develop new vegetative growth-producing foliage with highly soluble CP. Thus, this would explain why microbes in the rumen of sheep, in previous studies, and of cattle in this study, digested to a greater extent the CP in browse species during winter than during other seasons.

Lignin content in browse species evaluated by Ramírez-Orduña *et al.* (2003) was negatively correlated with EDCP in legumes ($r = -0.55$, $P<0.001$) and non-legumes ($r = -0.31$, $P<0.001$), but positively correlated with NDIP ($r = 0.36$ and 0.40 , $P<0.001$, in legumes and non-legumes, respectively) and with ADIP ($r = 0.61$ and 0.59 , $P<0.001$). Condensed tannins in legumes were positively correlated with NDIP ($r = 0.42$, $P<0.001$) and with ADIP ($r = 0.32$, $P<0.001$).

These results indicate that lignification in browse plants might be the most important factor in determining the protein distribution in the cell wall and, perhaps, protein fermentation. Moreover, condensed tannins in legume species might be a contributing factor in determining the protein availability of protein in the cell wall. However, it may be recognized that the structural features of lignin have a greater effect on ruminal cell wall degradation than the concentration of individual cell wall components (Jung and Deetz, 1993; Van Soest, 1994). Similarly, research on tannins in forage legumes has determined their variable effect on protein digestion (Reed, 1995; Butter *et al.*, 1999; Mueller-Harvey, 1999). However, more research on tannin structure in relation to digestion of specific proteins is needed.

Ruminants browsing shrub species such as those evaluated in this study, possibly metabolize nitrogen in a better way than those animals feeding only on alfalfa hay, as most of the protein from the latter may be more rapidly degraded. Thus, if ruminal microbes cannot utilize all of the aminoacids and ammonia released, it is suggested that more protein would have been degraded than synthesized. Otherwise, more concentrate has to be provided to maximize capture of the degraded forage protein for ruminal protein synthesis (Broderick, 1995). Conversely, nitrogen browse plants with lower NDSP and EDCP may pass through the rumen as aminoacids to the lower gut, and eventually be absorbed in the small intestine (Van Soest, 1994).

Even though there were variations in the seasonal dynamics of protein concentration, composition and degradation rates between legume and non-legume species, the protein content and effective degradation of CP of native legumes were highly influenced by the year (Table III). Also, during the three years evaluation of nutritional dynamics of the ten most important browse species from Baja California Sur, two periods could be detected: 1) a good forage quality period during the autumn and winter seasons, and 2) a low forage quality period in the spring and summer seasons. It seems that in non-legume species the main limiting factors of forage quality were the lower CP content and cell wall available CP (NDIP-ADIP), because during the low forage quality period the low concentration of CP negatively influenced the soluble fraction as well as EDCP, and increased the insoluble fractions (NDIP and ADIP).

In this study, *O. cholla*, a non-legume species, with the lowest CP content in all seasons and years, had the highest EDCP and potentially degradable CP, which means

that its CP is very soluble and degradable in the rumen of cattle (Table II). Other reports (Vadiveloo and Fadel, 1992; Hoffman *et al.*, 1993) have found a wide variation in protein degradation and composition between and within plant species, and have concluded that the species and maturity interactions is wide, so that the conventional classification of forages may not be a good reflection of the compositional and degradability attributes.

Conclusions

Two periods could be detected in the three years nutritional evaluation of the ten most important native browse species from Baja California Sur: 1) a good quality forage period, represented by the nutritional values of the legume species, in the autumn and winter seasons, and 2) a low quality forage period, which can be represented by the non-legumes, in the spring and summer seasons. During the worst quality forage seasons (spring and summer), legumes almost double non-legumes in CP and degradable CP content. Moreover, legumes such as *C. floridum* and *Prosopis* sp. were the most important legumes in the area, and are largely fermented in the rumen of steers, even more so than alfalfa hay. Conversely, non-legume species had low CP content and CP fermentation values. Only the non-legumes *O. cholla* and *C. edulis* had CP contents that were highly fermented in the rumen of steers. Therefore, it is recommended that legumes be conserved and promoted in these arid regions, because of their CP and CP in the cell wall that can be largely fermented and, consequently, could improve performance of animals feeding on them and sustain a good development of range ruminants.

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Seasonal Dynamics of Organic Matter Digestion in Browse Species from Baja California Sur, Mexico

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Abstract

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With the aim to estimate seasonally the rate and extent of organic matter degradability (EDOM), ten native species from Baja California Sur, Mexico were evaluated. Branches from the legumes: *Acacia peninsularis* (Brit. L. Rose) Standley; *Cercidium floridum* (Benth); *Mimosa xantii*, Gray;

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Pithecellobium confine (Standley) and *Prosopis* sp. (Torr) and non-legumes: *Bursera microphylla* Gray (Burceraceae); *Cyrtocarpa edulis* (Brand) Stand (Anacardiaceae); *Lippia palmeri*, S. Wats (Verbenaceae); *Opuntia cholla*, Weber (Cactaceae) and *Turnera diffusa* Wild (Turneraceae) were collected from 16 linear transects of 30m, located randomly. Collections were carried out in each season during three consecutive years. Non legumes species were significantly different in their EDOM during spring and summer, whereas legumes species were not affected by season. Differences between plant types were significant only during spring. *Cercidium floridum* and *O. cholla* had EDOM values comparable to alfalfa hay. Other plant species resulted with lower EDOM than alfalfa hay. *Turnera diffusa* had the lowest EDOM. It may appear that forage quality vary according to season, during fall and winter good quality and during the spring and autumn low quality forages are available.

Key words: Native shrubs, Baja California Sur, Mexico, chemical composition, effective degradability, organic matter.

Introduction

The improvement in the feeding of ruminants has been based on the development of mechanistic models that provides quantitative estimates of fermentation end products and materials that escape ruminal degradation (Russell *et al.*, 1992). However, the low or negative digestion coefficients of nitrogen (Woodward and Reed, 1995; McSweeney *et al.*, 1999) and cell wall constituents (Makkar *et al.*, 1997; McSweeney *et al.*, 1999) in plants containing condensed tannins, indicate that these fractions are digested in a different way. This lack in uniformity and the need of quantitative data of forage degradation under specific feeding conditions make it necessary to evaluate potential forage sources in arid and semiarid lands.

Baja California Sur, Mexico is considered as an extremely arid zone (FAO, 1987), 92 per cent of its flora is composed by shrubs and 23 per cent of these are endemic species (Breededa *et al.*, 1991). Livestock production systems, in these areas, are based mainly on grazing goats and beef cattle (Arriaga and Cancino, 1992) and most of the farmers are traditional smallholder; however, there is an extreme lack of information on the value of shrubs fodder for farm animals. The aim of this study was to evaluate and compare the

cell wall constituents and the rate and extent of organic matter digestion of leaves in five legumes and five non-legume native shrubs species from Baja California Sur. In this study, *Medicago sativa* hay was used as a reference species of good nutritional quality.

Materials and Methods

Site and collection area

This study was conducted in the ranch "Palmar de Abajo" (800 ha) located in La Paz, Baja California Sur ($23^{\circ} 38'40''$ north and $110^{\circ} 18'07''$ west). The climate of the region is arid with annual mean temperature of 22C and annual precipitation of 182 mm, mainly during the summer and winter seasons. Branches from five legumes: *Acacia peninsularis* (Brit. L. Rose) Standley; *Cercidium floridum* (Benth); *Mimosa xantii*, Gray; *Pithecellobium confine* (Standley) and *Prosopis* sp. (Torr) and five non-legumes: *Bursera microphylla* Gray (Burceraceae); *Cryptocarpa edulis* (Brand) Stand (Anacordiaceae); *Lippia palmeri*, S. Wats (Verbenaceae); *Opuntia cholla*, Weber (Cactaceae) and *Turnera diffusa* Wild (Turneraceae) were collected from 16 linear transects of 30 m, located randomly. Collections were carried out in each season of the year (winter, February 23; spring, May 23; summer, August 23 and fall, November 23), during three consecutive years. Branches were bulked in one sample of each species and were allowed to dry under shed. Leaves from branches were removed manually, oven dried (45C) and ground in a Willey mill (2 mm screen). Alfalfa hay (*Medicago sativa*) was used as a reference plant.

Chemical analyses

All species were analysed to determine dry matter, ash, organic matter (AOAC, 1990), neutral detergent fiber (NDF), hemicellulose, cellulose (Goering and Van Soest, 1970, modified by Van Soest *et al.*, 1991), lignin (AOAC, 1990) and condensed tannins (Burns, 1971, modified by Price *et al.*, 1978). Non-structural carbohydrates (NSC) content was also determined (Van Soest *et al.*, 1991).

Four rumen cannulated beef steers (250 ± 5.3 kg) were used to estimate the rate (kg %/h) and extent of organic matter loss (%) of

each plant species in each season and in each year. Nylon bags (10x15 cm and 50 µm of pore size) were incubated in the ventral part of the rumen of steers. During the trial steers were fed alfalfa hay (16% CP) *ad libitum*. Plant material (4g) was placed in nylon bags and suspended in the rumen of steers for 1, 2, 3, 4, 8, 12, 24, 48, 72 and 100 h, respectively. Zero-time disappearance was determined from unincubated bags. After incubation, the washed bags were dried at 60C in an oven for 48 h. The *in situ* digestibility of organic matter (ISDOM) of every period of incubation was calculated.

To estimate the non-linear characteristics of OM, *in situ* digestibility values from nylon bags were used in the following equation from Ørskov and McDonald (1979):

$$p = a + b (1 - e^{-kt})$$

where

P is the percentage of disappearance of the OM at time t,

a is the soluble fraction of the sample,

b is the insoluble fraction that is degraded slowly in the rumen,

c is a constant rate of disappearance of the fraction b, and

t is the incubation time.

The non-lineal parameters a, b and c, and the effective degradability of the OM (EDOM) = $(a+b)c/(c+kd)[e^{-c+kd/T}]$ was calculated using the computer program Neway (McDonald, 1981). Where kd represents the outflow rate from the rumen and T is the lag time. The EDOM values of browse leaves and *M. sativa* were estimated using an outflow rate of 2%/h.

Data from fiber fraction, rate of organic matter degradation and EDOM were analysed by analysis of variance, means of legumes and no legumes species were compared by contrasts. The season and year effect for each plant species and type (legume and non legume) was determined by auto regression analyses. The fall season was used as a base season for comparison. All statistical procedures were performed using SPSS 9.0 software (SPSS, 1999).

Results and Discussion

Chemical composition

The non-structural carbohydrates (NSC) in legumes and non-legumes were different ($P<0.001$) only in spring as compared to other seasons. Also during spring plants varied among themselves in their NSC content. However, when comparison was made among years, they were not different ($P>0.05$; Table 1a). During spring NDF content of some shrubs significantly decreased (*P. confine* and *M. xantii*), whereas others showed reverse trend (*C. edulis* and *T. diffusa*). In spring the NDF content was higher ($P<0.01$) in non-legumes than in legumes species.

Opuntia cholla, *L. palmeri* and *Prosopis sp.* had the highest hemicellulose content, whereas *B. microphylla* and *T. diffusa* had the lowest. The non-legume species were more variable in hemicellulose content than the legume species (Table 1a) but there were differences only in fall. Legumes species had lowest hemicellulose content during spring and summer, whereas the non-legumes had highest during winter (Table 1a).

In this study, except *L. palmeri* all plants in all seasons and years had lower cellulose content than alfalfa hay. *A. peninsularis* in fall and *B. microphylla* in spring had highest cellulose content. There were significant differences in winter and spring in cellulose content between non-legumes and legumes, non-legumes decreased their cellulose content during winter but increased it in spring, whereas the legume species did not show any seasonal effect (Table 1b).

All plants in all seasons had higher lignin content than that of *M. sativa* hay. *Bursera microphylla*, *P. confine* and *T. diffusa* showed the highest, and *C. floridium*, *O. cholla* and *Prosopis sp.* the lowest lignin content. Non-legumes were more variable in lignin content than legumes across seasons. During spring lignin content of non-legumes increased (Table 1b). Legumes were higher in condensed tannins than non-legumes. Only legumes species had a season effect. They resulted in the lowest tannin content during winter and spring (Table 1b).

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Table 1a
Seasonal dynamics of leguminous and non-leguminous native shrubs from Baja California Sur, México

Plants	Non-structural carbohydrates				Neutral detergent fiber				Hemicellulose			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
<i>Medicago sativa</i>	33.3	31.2	33.6	33.3	39.0	38.9	38.9	39.0	9.9	10.0	10.1	9.9
<i>Acacia penninervis</i>	37.0	41.6	34.5	37.9	40.2	35.4	35.2	37.7	13.2	7.3	6.7	7.7
<i>Cercidium floridum</i>	36.4	41.9	45.3	41.9	34.1	31.2	27.4	27.3	10.8	11.1	7.8	9.2
<i>Mimosa xanthii</i>	43.6	41.6	33.4	32.5	32.9	33.3	38.1	41.4	6.0	3.8	7.7	13.4
<i>Pithecellobium confine</i>	28.0	31.3	28.3	27.3	42.2	38.3	43.2	44.8	12.2	6.4	6.5	9.7
<i>Prosopis sp.</i>	34.4	33.8	28.0	32.2	36.5	37.7	39.5	39.7	13.1	14.0	14.9	15.9
Leguminous	36.9	38.0	33.9	34.4	37.2	35.2	36.7	38.2	11.1	8.5	8.7	11.2
<i>Bursera microphylla</i>	45.0	28.9	47.4	48.9	31.8	52.3	28.4	28.3	5.9	2.5	3.7	5.3
<i>Cyrtocarpa edulis</i>	42.3	39.5	44.7	37.2	32.3	39.0	33.7	30.5	8.7	8.3	15.4	6.9
<i>Lippia palmeri</i>	31.7	17.9	27.4	30.5	47.1	65.3	55.6	44.9	9.5	15.1	8.9	11.5
<i>Opuntia cholla</i>	36.1	38.8	32.7	37.1	42.3	36.3	34.7	37.9	22.1	15.8	15.9	11.1
<i>Turnera diffusa</i>	33.0	28.8	27.2	36.8	45.3	55.7	50.9	40.9	15.1	9.3	3.6	5.5
Non-Leguminous	37.6	30.8	36.5	37.9	39.8	49.7	39.6	36.5	12.8	10.2	9.5	8.1

Cont....

Plants	Non-structural carbohydrates			Neutral detergent fiber			Hemicellulose					
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Effect: Season¹												
Leguminous	ns	**	ns		ns	**	ns		ns	***	***	
AR	1.7	3.8	-0.4		-0.8	-3.4	-2.1		0.1	-3.2	-3.1	
Non-leguminous	ns	***	ns		ns	***	ns		**	ns	ns	
AR	-0.6	-7.6	-3.2		3.7	13.7	4.8		4.3	2.2	1.8	
Effect Plant Type²												
Contrast	ns	**	ns	ns	ns	***	ns	ns	ns	ns	ns	*
SE	1.8	2.4	2.5	2.1	9.9	12.6	14.2	10.1	1.7	1.6	1.6	1.3

¹Significance and autoregression coefficient (AR) for season comparisons with respect to fall.²Significance and standard error (SE) of contrast between plant types by ...

***P<0.001; **P<0.01; *P<0.05; ns=not significant.

Organic matter degradation rate

All studied species had a lower organic matter degradation rate (%/h) than alfalfa hay (Table 2). *Acacia peninsularis*, *C. edulis*, *M. xantii* and *P. confine* had the lowest degradation rate. It increased ($P<0.01$) in spring and winter for *M. xantii* and *P. confine*, respectively. Other species were not different ($P>0.05$) among seasons. Organic matter degradation rate of legumes was lower than in non-legumes in all seasons and it increased during winter and spring, whereas non-legumes species were not affected by the season (Table 2).

Effective degradability of organic matter (EDOM)

EDOM of non-legumes decreased during spring and summer, whereas legumes were not affected by season. Differences between plant types were significant only in spring (Table 2). *Cercidium floridum* and *O. cholla* were comparable to alfalfa hay. Other plant species resulted in lower EDOM than alfalfa hay.

It may appear that good quality forages are available during the fall and winter seasons. The low NDF and condensed tannins content in shrubs and the concomitant increase in NSC and EDOM in legumes during spring might indicate a better forage quality than non-legumes. Hoffman *et al.* (1993) found that legumes exhibited more ruminal dry matter degradation than did grasses, however they reported extensive differences in ruminal degradation kinetics between perennial legumes and non-legumes species and maturities. In this study, EDOM and NSC content of non-legumes decreased in spring and summer and cell wall components were increased in spring at the time of crop maturity. Nelson and Moser, 1994 and Van Soest, 1994 supported that the maturity effect in legumes is determined by a decrease in the leaf:stem ratio with little effect on nutritive constituents. Moreover, lignin content appear to be the most important component limiting EDOM in leguminous ($r= -0.56$, $P<0.001$) and non-leguminous ($r= -0.69$, $P<0.001$) species, however, there were wide variations in EDOM interspecies and intraspecies within seasons varying from 30.5 to 69.4 in non-legumes and from 46.1 to 70.2 in legumes species. Other studies have found a high variation within and among plant species (Hoffman *et al.*, 1993;

Table 1b
Seasonal dynamics of leguminous and non-leguminous native shrubs from Baja California Sur, México

Plants	Cellulose			Lignin, as % of NDF			Condensed tannins					
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
<i>Medicago sativa</i>	19.9	20.3	20.0	19.9	7.2	7.3	7.0	7.2	0.0	0.0	0.0	0.0
<i>Acacia penninsularis</i>	12.6	11.6	12.3	15.0	14.4	16.0	16.0	14.7	7.6	7.1	7.5	6.8
<i>Cercidium floridum</i>	10.2	12.1	6.9	4.5	17.1	7.5	12.3	13.3	8.8	8.1	9.9	10.4
<i>Mimosa xanitii</i>	9.7	10.9	9.2	10.5	15.3	17.1	17.7	17.1	6.5	5.9	7.4	8.8
<i>Pithecellobium conifine</i>	10.7	11.2	11.9	13.6	19.2	19.6	24.5	21.9	7.9	7.4	8.5	8.4
<i>Prosopis</i> sp.	34.4	33.8	28.0	32.2	36.5	37.7	39.5	39.7	13.1	14.0	14.9	15.9
Leguminous	10.9	12.0	10.3	11.4	15.5	13.9	16.5	15.4	6.2	5.8	6.8	7.0
<i>Bursera microphylla</i>	6.2	18.3	9.6	8.8	16.4	31.0	16.2	13.9	4.4	5.9	6.1	5.7
<i>Cyrtocarpa edulis</i>	7.6	12.6	10.2	12.1	14.9	22.3	14.9	11.1	8.3	6.9	8.4	9.0
<i>Lippia palmeri</i>	18.5	26.4	27.6	21.3	18.4	23.2	18.6	11.1	0.0	0.0	0.0	0.0
<i>Opuntia cholla</i>	9.5	12.1	12.8	13.4	10.5	8.2	9.1	11.5	0.0	0.0	0.0	0.2
<i>Turnera difusa</i>	7.7	20.0	20.1	18.7	23.8	25.7	24.4	17.2	6.9	4.0	5.5	6.0
Non-Leguminous	9.9	17.9	15.2	14.9	16.8	22.1	16.5	18.0	3.9	3.8	4.2	4.1

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Plants	Cellulose			Lignin, as % of NDF			Condensed tannins					
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Effect: Season¹												
Leguminous	ns	ns	ns		ns	ns	ns		***	***	***	ns
AR	-0.6	0.5	-1.0		0.4	-1.1	1.0		-1.3	-1.4	-0.3	
Non-leguminous	**	**	ns		ns	***	ns		ns	ns	ns	
AR	-4.1	4.5	2.1		3.7	8.8	3.5		-0.1	-0.7	-0.1	
Effect: Plant Type²												
Contrast	ns	***	**		**	ns	*		***	***	***	***
SE	1.5	1.4	1.6		1.2	1.8	2.2		1.5	1.0	3.1	3.5

¹Significance and autoregression coefficient (AR) for season comparisons with respect to fall.²Significance and standard error (SE) of contrast between plant types by season.

***P<0.001; **P<0.01; *P<0.05; ns=not significant; NDF=neutral detergent fiber.

Table 2
 Seasonal dynamics of the rate of degradation of the organic matter
 (%/hour) and organic matter degradability (%) in leguminous and
 non-leguminous native shrubs from Baja California Sur, México

Plant	Degradation rate of OM				EDOM			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
<i>Medicago sativa</i>	11.1	17.2	13.3	12.4	65.2	66.3	67.0	69.2
<i>Acacia peninsularis</i>	4.7	5.1	3.6	4.0	57.9	60.8	61.9	59.3
<i>Cercidium floridum</i>	6.2	8.9	5.2	6.1	70.2	69.2	67.2	70.2
<i>Mimosa xantii</i>	5.4	6.1	3.6	2.4	59.6	59.7	56.9	58.3
<i>Pithecellobium confine</i>	6.8	6.4	3.1	2.4	50.4	51.9	47.1	46.1
<i>Prosopis sp.</i>	9.5	8.4	8.4	6.9	62.5	61.6	60.7	62.9
Leguminous	6.5	7.0	4.8	4.4	60.1	60.6	58.8	59.4
<i>Bursera microphylla</i>	10.7	9.4	11.2	8.6	62.0	30.5	68.9	67.3
<i>Cyrtocarpa edulis</i>	6.5	7.7	1.1	3.9	62.3	45.5	49.3	58.5
<i>Lippia palmeri</i>	11.4	9.0	12.1	11.2	54.1	32.2	42.8	60.1
<i>Opuntia cholla</i>	8.7	10.5	11.3	8.7	69.4	65.9	67.4	64.4
<i>Turnera difusa</i>	12.5	12.1	8.2	13.2	48.5	33.7	40.6	52.0
Non-Leguminous	9.9	9.7	8.6	9.1	59.2	41.5	54.6	60.5
Effect: Season ¹								
Leguminous	***	**	ns		ns	ns	ns	
AR	0.02	0.02	0.01		1.3	2.3	0.2	
Non-leguminous	ns	ns	ns		ns	***	***	
AR	0.02	0.01	0.00		-1.3	-18.7	-7.2	
Effect: Plant Type ²								
Contrast	***	**	***	***	ns	***	ns	ns
SE	0.006	0.008	0.008	0.006	1.8	2.2	2.4	1.6

¹Significance and autoregression coefficient (AR) for season comparisons with respect to fall.

²Significance and standard error (SE) of contrast between plant types by season.

***P<0.001; **P<0.01; *P<0.05; ns=not significant.

EDOM=effective degradability of organic matter calculated with a 5%/h ruminal turnover rate.

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Larbi *et al.*, 1997), and have concluded that the species and maturity interactions are wide making that the conventional classification of forages may not be a good reflection of the composition and degradability attributes.

It has been concluded that non-legumes species had a seasonal effect on fiber fractions and effective degradability of organic matter. *Opuntia cholla* may be as valuable as legumes during the spring and summer for providing rumen degradable organic matter. The lignin content may be the most important constituent limiting the rumen degradable organic matter in leguminous and non-leguminous species studied.

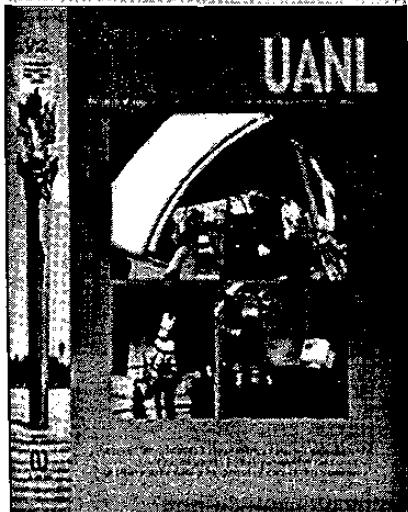
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Fotos del Planetario Alfa, correspondientes al Observatorio y al área ilusión y razón, tomadas por Pablo Cuéllar y procesadas artísticamente por medios electrónicos por Francisco Barragán Coadean.

Información en detalle en el reportaje: "El Planetario Alfa" de Vanessa Herrera.

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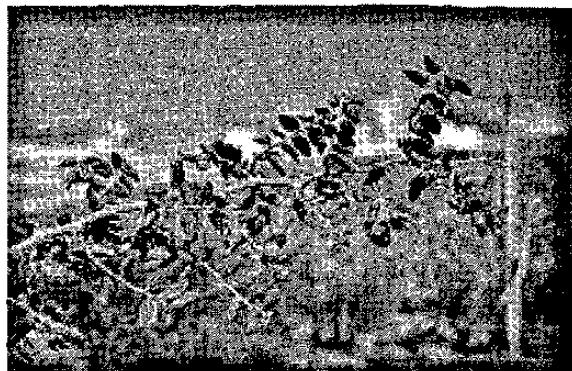
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Factores estructurales de la pared celular del forraje que afectan su digestibilidad

Rafael Ramírez Orduña,* Roque Gonzalo Ramírez Lozano,** Francisco López Gutiérrez***

Los rumiantes han desarrollado la habilidad de utilizar el material vegetativo de las plantas como su única fuente de nutrientes, por medio de los microorganismos que alojan en su rumen. Aproximadamente del 35 a 80% de la materia orgánica (MO) de los tejidos vegetales está contenida en la pared celular, la cual proporciona rigidez estructural a la planta. Sin embargo, los rumiantes que dependen exclusivamente de las plantas consumidas en libre pastoreo obtienen sólo de un 30 a 40% de la energía digestible consumida de la pared celular del forraje.¹ Se han reportado animales que consumen altos niveles de forraje con alta concentración de pared celular y tienen baja digestibilidad y, por lo tanto, la disponibilidad de energía en su dieta es limitada.² Dependiendo de la constitución de la pared celular, su digestibilidad varía; de 100% en las células mesófilas a 0% en el xilema, esta variación ocurre en diferentes tejidos dentro de una parte de planta y entre tejidos similares en diferentes especies de forraje.³

Dependiendo del tipo de tejido y a medida que la célula de la planta madura, la pared celular se ensancha y comúnmente produce una pared secundaria de composición distinta con una notable deposición de constituyentes aromáticos, por lo que ocurren concomitantemente cambios químicos y anatómicos, afectando la digestibilidad. Sin embargo las diferencias en estructura pueden o no influir significativamente la tasa y grado de digestión del forraje; por ejemplo, las diferencias conformacionales entre la orientación de los componentes fenólicos relativas a los polisacáridos con los que se asocian, pueden sólo ser importantes si dichos polisacáridos contribuyen, en cantidades significantes, a la composición total de un tipo particular de tejido susceptible a la degradación. Asimismo, es posible que una mo-



Celtis pallida (granjeno).

derada lignificación pueda limitar el acceso microbial a los tejidos y un mayor grado de lignificación no tenga ningún efecto a menos que se disemine a otros tejidos.⁴

Generalidades sobre la pared celular

Descubrimientos recientes han cambiado la noción sobre la estructura rígida y estática asignada a la pared celular, por la de una extensión virtual del citoplasma. Se ha encontrado que las paredes celulares, particularmente las primarias, poseen marcadores de superficie que predicen patrones de desarrollo y marcan posiciones dentro del vegetal,^{5,6} asimismo, contienen componentes de señalamiento y co-

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municación por la continuidad simplástica mediante los plasmodesmos.⁷

Las paredes celulares también mantienen continuación molecular con la membrana plasmática y el citoesqueleto⁸ y conexiones firmes con la membrana plasmática, debido a adaptaciones al estrés osmótico.⁹ Señales de la pared celular provocadas por la predación de insectos inducen la producción de moléculas de defensa,¹⁰ formándose capas de proteínas y lignina, como respuesta a la invasión de patógenos fungales y virales.^{11,12}

Por otra parte, para que las células alcancen su forma funcional e individualidad tienen que elongarse y diferenciarse. La expansión coordinada y la diferenciación de las células individuales se logran por alteraciones sutiles de la estructura química de los componentes de la pared y las determinantes mecánicas de la forma de la célula.^{13,14}

Así, se puede apreciar que la pared celular primaria es una matriz extracelular químicamente dinámica, con un mosaico de respuestas y llena de diversas formas y funciones. Existen grupos de trabajo a escala mundial que estudian la pared celular desde varios ángulos: sus propiedades físicas y químicas, su participación en la resistencia a enfermedades, en el reconocimiento celular, como fuente de oligosacáridos con actividad biológica, y su digestibilidad.

Fibra detergente y fibra dietaria

El sistema de análisis que usa detergentes fue originalmente desarrollado para resolver el problema analítico relativo a la dieta de rumiantes, específicamente de forrajes. El objetivo del análisis es fraccionar el alimento en entidades químicas de acuerdo a su disponibilidad nutritiva¹⁵. La fibra es un producto analítico con características nutricionales que describe a aquellos componentes del forraje de baja solubilidad en un sistema de solventes específicos (detergente ácido y neutro) y son relativamente menos digestibles que el almidón. Este sistema reconoce que las asociaciones fisicoquímicas de los macropolímeros constituyentes son más importantes en determinar su disponibilidad que la composición química intrínseca. Basándose en esto, Van Soest¹⁶ señala que este sistema reconoce dos fracciones: La primera fracción (soluble en detergente neutro) corresponde al contenido celular, compuesta por carbohidratos no estructurales, lípidos, la mayor parte

de las proteínas y fibra soluble (también llamada polisacáridos no-almidón), esta última corresponde a las pectinas y b-glucanos, los cuales son solubles pero resistentes a las enzimas de mamíferos, son componentes de la pared celular que no tienen enlaces covalentes con la lignina y están completamente disponibles a la fermentación en el rumen.

La segunda fracción (insoluble en detergente neutro) corresponde a la pared celular insoluble, cuya disponibilidad está controlada por las características estructurales que ligan a la celulosa, hemicelulosas y lignina. Como pasos posteriores, las hemicelulosas son disueltas en detergente ácido, y la fracción insoluble (fibra detergente ácido), representada por lignina y celulosa principalmente, puede ser tratada con permanganato de potasio o ácido sulfúrico, para separar la celulosa de la lignina. En el campo de la nutrición humana y de animales no rumiantes, se han desarrollado otros métodos gravimétricos para el aislamiento de todas las fracciones resistentes a las enzimas de mamíferos, incluyendo la llamada fibra soluble, dentro de estos el método de Prosky¹⁶ ha sido reconocido por la AOAC¹⁷ como un procedimiento válido para la determinación de fibra dietaria total.

Aparentemente no existen sistemas químico-analíticos que separen a los carbohidratos estructurales en fracciones digestibles e indigestibles. Dicha separación es más obtenida por el uso de bacterias ruminantes, por métodos enzimáticos o por pruebas de digestibilidad *in vivo* e *in situ*.¹⁸

Estructura y digestibilidad de la pared celular

La estructura y función de la pared celular está controlada por la composición y organización de los componentes individuales. La pared celular está compuesta principalmente de azúcares dispuestos en polisacáridos de composición y estructura variable, ácido hidroxicinámico, lignina, proteína, iones y agua.^{19, 20}

Los estudios sobre la composición de la pared celular y digestibilidad generalmente utilizan tejidos de plantas, que son una mezcla homogénea de tipos celulares. Las paredes de diferentes tipos celulares varían mucho en sus características de digestión, por lo que dichos estudios son difíciles de interpretar a escala molecular, debido a la mezcla de características químicas y de digestión de los muchos tipos



Acacia greggi (uña de gato).

celulares.^{21,22}

La caracterización estructural de la pared de tipos celulares individuales es crítica para la determinación de la relación de los componentes de la pared y la digestibilidad; sin embargo, existen pocos estudios cuantitativos sobre la composición de los diferentes tipos celulares, debido a las dificultades en la separación de los tipos específicos de células en los tejidos de las plantas.²³

Estudios con tipos celulares de *Lolium perenne* y *L. multiflorum* reportan que el contenido de xilosa fue mayor en la pared celular de células fibrosas que en las mesófilas, reflejando un mayor contenido de hemicelulosa en las células fibrosas, la concentración de ácidos fenólicos eterificados y grupos acetilo también fueron considerablemente mayores en las células fibrosas²³. Las células mesófilas fueron degradadas más rápido que las fibrosas, no encontrándose evidencias de una degradación preferencial de algún polisacárido componente de la pared celular durante la fermentación, dado que los monosacáridos constituyentes desaparecieron a una tasa similar a la desaparición de la materia seca (MS). Los autores concluyen que el grado de lignificación y la formación de complejos lignina-carbohidratos son los factores que controlan la degradación de la pared. Este y otro trabajo con paja de cebada indican que todos los polisacáridos dentro de la matriz de la pared celular son igualmente afectados por la lignificación.²³

En otros estudios, la tasa de degradación de la celulosa no cambió cuando la pared celular fue delignificada; sin embargo, la reducción en el tamaño de partícula (lo cual incrementa el área superfi-

cial) tuvo un efecto positivo sobre la degradación de la celulosa. La delignificación incrementó la tasa de degradación de polisacáridos no celulósicos en un grado mayor que la reducción del tamaño de partícula, por lo que los autores consideran que las características estructurales limitan la degradación de la celulosa más que la lignina, pero que la lignina tiene un efecto más profundo sobre los polisacáridos no celulósicos dentro de la matriz de la pared celular.²⁴

El grado de digestión diferencial de los monosacáridos se ha interpretado como indicador de la remoción selectiva de la celulosa y hemicelulosas con alto grado de sustitución. Sin embargo, las diferencias observadas en la digestibilidad de monosacáridos pueden ser explicadas por diferencias en composición entre la pared primaria y la pared secundaria lignificada. En trabajos con *Brassica oleracea* y alfalfa, la fracción de hemicelulosa solubilizada por KOH 4 M no fue tan fácilmente degradada como otros polisacáridos, mientras que la delignificación parcial de células del xilema resultaron en un incremento en la degradación. En estos trabajos, empleando diferentes tipos de tejidos se ha observado una resistencia selectiva de fracciones de carbohidratos, principalmente xilanos. Aunque está claro que la lignificación tiene el principal impacto sobre la degradación de la pared celular, su efecto puede no ser uniforme como en los pastos. Se puede interpretar que lo anterior es un reflejo de la degradación diferencial de tipos celulares y que la baja degradación de la xilosa indica que algunas paredes no contienen xilanos y son degradadas más fácilmente, mientras que otras contienen grandes cantidades y son de lenta degradación, pero algunos xilanos son más fácilmente degradados de algunas paredes celulares que de otras.²⁵

La lignificación de la pared celular de las plantas ha sido correlacionada con una reducción en la degradabilidad de la MS²⁶ y la concentración *in vitro* de ácidos grasos volátiles²⁷ del forraje de arbustos que crecen en México, similarmente el contenido de lignina también ha sido relacionado a una baja digestibilidad *in vitro*²⁸ e *in situ*²⁹ de la MS y concentración *in vitro* de ácidos grasos volátiles²⁹ en hojas de arbustos de México (tabla 1). Lo anterior puede ser debido a una baja digestibilidad de los polisacáridos estructurales, aunque los mecanismos responsables no han sido establecidos²³, hay una creciente especulación de que la utilización de la pared celu-

Tabla 1. Medias anuales de los componentes de la pared celular, degradabilidad efectiva de la materia seca (%) y concentración in vitro de ácidos grasos volátiles (AGV, mM) en arbustivas de México.

Especie	Pared celular	Celulosa	Hemilignina	Taninos	DEMS	AGV
<i>Helietia parvifolia</i> ^a	19.0	14.0	1.0	4.0	0.2	76.2 69.0
<i>Celtis Pallida</i> ^a	23.0	11.0	6.0	4.5	0.1	76.4 47.0
<i>Bernardia myricaefolia</i> ^a	29.0	18.0	4.0	6.6	0.4	63.0 55.0
<i>Pithecellobium pallens</i> ^a	36.0	17.0	11.0	7.4	0.6	60.8 48.0
<i>Caesalpinia mexicana</i> ^a	28.0	13.0	7.0	7.6	0.3	65.9 43.0
<i>Eysenhardtia polystachya</i> ^a	34.0	11.0	15.0	8.4	0.2	63.1 51.0
<i>Gimnosperma glutinosum</i> ^a	25.0	11.0	4.0	10.4	4.4	63.9 27.0
<i>Diospyros texana</i> ^a	33.0	15.0	7.0	10.7	2.1	56.2 39.0
<i>Parkinsonia aculeata</i> ^a	49.0	23.0	15.0	11.1	0.04	47.4 35.0
<i>Pithecellobium ebeno</i> ^a	50.0	12.0	19.0	19.5	0.7	38.7 24.0
<i>Cyrtocarpa edulis</i> ^b	34.0	13.0	9.0	10.0	6.2	45.5 65.2
<i>Acacia peninsularis</i> ^b	37.0	16.0	9.0	12.0	5.7	49.1 49.5
<i>Prosopis sp</i> ^b	34.0	11.0	10.0	12.0	.5	59.5 69.9
<i>Cercidium floridum</i> ^b	27.0	14.0	70.	6.0	6.4	60.0 72.3
<i>Mimosa xanti</i> ^b	34.0	22.0	4.0	7.0	5.4	45.8 61.7
<i>Tumera difusa</i> ^b	40.0	17.0	8.0	12.0	5.9	49.8 55.8
<i>Bursera microphylla</i> ^b	32.0	16.0	3.0	13.0	2.9	55.4 58.5
<i>Opuntia cholla</i> ^b	41.0	12.0	20.0	8.0	0.3	63.0 76.9
<i>Pithecellobium confine</i> ^b	40.0	18.0	7.0	14.0	5.7	40.0 58.1
<i>Lippia palmeri</i> ^b	43.0	13.0	8.0	21.0	0.3	56.1 61.5

^a Tomado de Ramírez et al. (28) y Ramírez et al. (29), ^b Tomado de Ramírez-Orduña et al. (26-27); DEMS= degradabilidad efectiva de la materia seca a una tasa de recambio ruminal de 2%/hora

lar del forraje como fuente de energía está regulada por la naturaleza de enlaces cruzados de los componentes de la pared.³⁰

La cantidad de lignina puede ser el factor clave que límite la degradación de la pared celular; sin embargo la organización de la matriz de la pared, en la cual se encuentra la lignina, puede regular el grado de su influencia sobre la degradación de los polisacáridos de la pared.²³

Se han propuesto tres posibles mecanismos mediante los cuales la lignificación puede limitar la fermentación microbial o hidrolisis enzimática de los polisacáridos de la pared celular: 1) un efecto tóxico de la lignina sobre los microorganismos del rumen; 2) impedimento estérico causado por los enlaces lignina-polisacáridos que limita el acceso de enzimas a carbohidratos específicos y 3) un medio ambiente hidrofóbico creado por la lignina que impide la acción de enzimas, las cuales requieren un medio acuoso.³¹

Jung y Deetz³¹ hacen una revisión de estos mecanismos y concluyen que la hidrofobicidad y la toxicidad de la lignina son mecanismos de inhibición que

son poco probables de afectar cuantitativamente la degradación de la pared celular en el rumen en un grado significante, y que el impedimento estérico parece ser el mecanismo principal que limita la degradación de la pared celular.

Otro factor en el forraje, además de la lignina, que limita la degradación de la pared celular es la cutícula que contiene ceras y polímeros cerosos, su efecto sobre la degradación parece estar limitado a la membrana cuticular.¹⁸ La cutina, ceras y suberina pueden influir la digestión, la cutina y las ceras están adheridas a la pared de la epidermis sobre la superficie de la planta. La cutina está frecuentemente esterificada con ácidos fe-

nólicos y en asociación no covalente con la pectina de la pared celular epidermal. Estos compuestos forman una barrera disfuncional que impide la digestibilidad del tejido intacto.⁴⁻¹⁸ La suberina, a diferencia de la cutina, es una parte integral de la pared celular y puede estar esterificada con monómeros, oligómeros fenólicos y lignina.⁴

La sílice tiene efecto negativo sobre la digestibilidad de los pastos, causando un decremento de un 3% en la digestibilidad in vitro de la MS por unidad de incremento de sílice, principalmente por decremento en la digestión de los polisacáridos de la pared celular.³² El contenido de sílice se ha encontrado que está asociado con una baja digestibilidad de la fibra e interactúa con la lignina.³³

La presencia de taninos en la fibra detergente neutro (FDN) y fibra detergente ácido (FDA) indica que los taninos están fuertemente ligados a la fibra.¹⁸ La fibra ligada a taninos puede resistir su degradación por los microorganismos ruminantes y también los taninos libres pueden inactivar los microorganismos y sus enzimas. Consecuentemente la fermentación pudiera ser inhibida en el rumen. Bae et al.³⁴

estudiaron el efecto de los taninos condensados provenientes de *L. corniculatus* sobre la bacteria ruminal *Fibrobacter succinogenes* S85. Ellos observaron que los efectos inhibitorios de los taninos condensados sobre la digestión de la celulosa pudieran deberse no sólo a la inactivación de enzimas extracelulares, sino que también pudiera estar involucrado una interferencia en la adhesión de la bacteria sobre la celulosa. La inhibición de la digestión de la celulosa pudiera producir una reducción en la producción de energía metabolizable en el rumen. Por lo tanto, se daría una inhibición en la producción de ácidos grasos volátiles, en un sistema ruminal *in vitro*, causada por la presencia de taninos condensados purificados de *L. corniculatus*.³⁵ La disponibilidad de la proteína microbial rica en aminoácidos esenciales puede ser limitada debido a los efectos bacteriostáticos y bactericidas de los taninos en el rumen.³⁶

En las tablas 2 y 3 se muestran la relación entre los componentes de fibra y la degradabilidad efectiva de la pared celular (DEPC) y digestibilidad in

vivo de la pared celular (DIVPC) de algunas arbustivas forrajeras que crecen en México y, como componentes de dietas para rumiantes. En general, estas plantas y las dietas contienen bajos porcentajes de pared celular, pero alto contenido de lignina y taninos condensados en comparación con otros grupos de plantas como serían los pastos. Aparentemente, cuando el contenido, ya sea de lignina o de taninos condensados es elevado, la DEPC o DIVPC son bajas, independientemente del contenido de pared celular en el forraje o en la dieta.

La identificación de factores estructurales específicos, limitantes de la degradación es compleja y la importancia relativa de cada uno de ellos puede variar con la madurez del forraje; sin embargo, esta información puede contribuir en gran medida a incrementar la utilización de la energía contenida en la pared celular del forraje. Esto puede sentar las bases para programas de mejoramiento genético o de manipulación biotecnológica, dirigidos a eficientar la utilización de recursos forrajeros tanto doméstica-

Tabla II. Relación entre los constituyentes de la pared celular y la degradabilidad efectiva de la pared celular de arbustos que crecen en México, colectadas durante la primavera de 1993^a y 1999.^b

Plantas arbustivas	Pared celular %	Celulosa %	Hemicelulosa %	Lignina %	Taninos %	DEPC %
<i>Acacia rigidula</i> ^a	52.3	17.9	17.2	17.2	15.2	13.4
<i>Cercidium macrum</i> ^a	24.8	4.9	10.2	9.7	3.9	48.2
<i>Acacia farnesiana</i> ^a	37.7	9.0	14.0	14.3	1.8	30.7
<i>Portieria angustifolia</i> ^a	38.7	14.4	10.8	13.6	0.5	32.9
<i>Celtis pallida</i> ^a	33.7	10.8	19.4	3.5	0.3	74.3
<i>Acacia berlandieri</i> ^a	36.6	10.8	9.6	16.2	13.2	10.8
<i>Leucaena leucocephala</i> ^a	32.4	38.7	15.6	8.3	7.5	53.7
<i>Leucophyllum texanum</i> ^a	44.5	11.2	22.3	22.3	0.4	33.4
<i>Desmanthus virgatus</i> ^a	25.9	6.1	9.1	10.8	8.9	47.0
<i>Acacia greggii</i> ^a	41.9	21.5	10.5	10.0	3.4	34.5
<i>Cordia boissieri</i> ^a	35.9	20.5	9.5	5.9	0.3	38.2
<i>Condalia obovata</i> ^a	29.2	6.4	12.0	10.8	0.9	54.5
<i>Ziziphus obtusifolia</i> ^a	26.0	6.0	8.9	11.1	13.7	39.1
<i>Prosopis glandulosa</i> ^a	47.1	19.4	11.7	16.1	0.2	26.1
<i>Opuntia lindheimeri</i> ^a	47.1	12.8	32.2	2.2	0.2	67.8
<i>Acacia wrightii</i> ^b	41.8	19.5	9.5	12.8	0.2	43.2
<i>Burmelia celastina</i> ^b	35.7	13.9	2.3	19.4	0.0	36.0
<i>Castela texana</i> ^b	45.7	9.1	13.7	22.0	3.5	54.2
<i>Forestiera angustifolia</i> ^b	50.9	9.9	27.7	13.0	0.0	66.3
<i>Karwinskia humboldtiana</i> ^b	39.8	8.4	14.4	16.9	1.2	61.3
<i>Larrea tridentata</i> ^b	26.7	8.9	3.2	12.6	0.9	35.7
<i>Schaefferia cuneifolia</i> ^b	47.6	9.3	18.8	18.9	0.0	48.6
<i>Zathoxylum fagara</i> ^b	40.1	11.1	18.4	9.8	0.0	40.7

^aObtenido de Ramírez et al. (37); ^bobtenido de Moya-Rodríguez et al.(38); DEPC = degradabilidad efectiva de la pared celular estimada a una tasa de recambio ruminal del 2%/hora.

Tabla II. Relación entre los constituyentes de la pared celular y la degradabilidad efectiva de la pared celular de arbustos que crecen en México, colectadas durante la primavera de 1993^a y 1999^b

Plantas arbustivas	Pared celular %	Celulosa %	Hemicelulosa %	Lignina %	Taninos %	DEPC %
<i>Acacia rigidula</i> ^a	52.3	17.9	17.2	17.2	15.2	13.4
<i>Cercidium macrum</i> ^a	24.8	4.9	10.2	9.7	3.9	48.2
<i>Acacia farnesiana</i> ^a	37.7	9.0	14.0	14.3	1.8	30.7
<i>Porlieria angustifolia</i> ^a	38.7	14.4	10.8	13.6	0.5	32.9
<i>Celtis pallida</i> ^a	33.7	10.8	19.4	3.5	0.3	74.3
<i>Acacia berlandieri</i> ^a	36.6	10.8	9.6	16.2	13.2	10.8
<i>Leucaena leucocephala</i> ^a	32.4	38.7	15.6	8.3	7.5	53.7
<i>Leucophyllum texanum</i> ^a	44.5	11.2	22.3	22.3	0.4	33.4
<i>Desmanthus virgatus</i> ^a	25.9	6.1	9.1	10.8	8.9	47.0
<i>Acacia greggii</i> ^b	41.9	21.5	10.5	10.0	3.4	34.5
<i>Cordia boissieri</i> ^a	35.9	20.5	9.5	5.9	0.3	38.2
<i>Condalia obovata</i> ^a	29.2	6.4	12.0	10.8	0.9	54.5
<i>Ziziphus obtusifolia</i> ^a	26.0	6.0	8.9	11.1	13.7	39.1
<i>Prosopis glandulosa</i> ^a	47.1	19.4	11.7	16.1	0.2	26.1
<i>Opuntia lindeheimeri</i> ^a	47.1	12.8	32.2	2.2	0.2	67.8
<i>Acacia wrightii</i> ^b	41.8	19.5	9.5	12.8	0.2	43.2
<i>Bumelia celastina</i> ^b	35.7	13.9	2.3	19.4	0.0	36.0
<i>Castela texana</i> ^b	45.7	9.1	13.7	22.0	3.5	54.2
<i>Forestiera angustifolia</i> ^b	50.9	9.9	27.7	13.0	0.0	66.3
<i>Karwinskia humboldtiana</i> ^b	39.8	8.4	14.4	16.9	1.2	61.3
<i>Larrea tridentata</i> ^b	26.7	8.9	3.2	12.6	0.9	35.7
<i>Schaefferia cuneifolia</i> ^b	47.6	9.3	18.8	18.9	0.0	48.6
<i>Zanthoxylum fagara</i> ^b	40.1	11.1	18.4	9.8	0.0	40.7

^aObtenido de Ramírez et al. (37); ^bobtenido de Moya-Rodríguez et al.(38); DEPC = degradabilidad efectiva de la pared celular estimada a una tasa de recambio ruminal del 2%/hora.

dos como silvestres nativos.

Resumen

La naturaleza de enlaces cruzados de los componentes de la pared celular y la cantidad de lignina y taninos condensados pueden ser los factores clave que limiten su degradación; sin embargo, la organización de la matriz puede regular el grado de influencia de la lignina sobre la degradación de los polisacáridos de la pared. Su efecto parece no ser igual en arbustos y pastos. El impedimento estérico parece ser el mecanismo principal que limita la degradación. Esto parece aplicarse a arbustos nativos de zonas áridas, la identificación de factores limitantes específicos, como la lignina y los taninos, pueden contribuir a incrementar la utilización de la energía de la pared celular del forraje.

Palabras clave: Pared celular, Fibra, Estructura, Digestibilidad, Rumiantes.

Abstract

The cross-linked nature of the wall components, the amount of lignin and condensed tannins may be the key limitation to the cell-wall degradation; however, the organisation of the wall matrix would regulate the extent of lignin influence on degradation of the wall polysaccharides. This effect would not appear to be similar in legumes as in grasses. The steric hindrance would appear to be the major mechanism limiting forage cell wall degradation. This seems to apply to native shrubs from arid zones; the identification of specific limiting-factors such as lignin and tannins may contribute to enhancing the utilisation of forage cell wall energy.

Keywords: Cell wall, Fiber, Structure, Digestibility, Ruminants.

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Tabla III. Relación entre los componentes de la pared celular (% de la materia seca) de dietas de rumiantes conteniendo arbustivas nativas mezcladas con pajas de bajo valor nutritivo y la digestibilidad in vivo (%) de la pared celular

Estudio y especie animal	Relación de ingredientes en la dieta	Pared celular	Celulosa	Hemicelulosa	Lignina	Taninos	DIVPC
Ramírez et al. (39) Borregos Pelibuey x Rambouillet	-49.2% <i>M. sativa</i> + 50.8% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral -36.2% <i>Celtis pallida</i> + 63.8% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral -43.9 <i>Ziziphus obtusifolia</i> + 56.1% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral	56.8 54.9 53.4	24.5 18.5 20.6	21.7 22.9 18.7	8.6 9.3 12.3	0.0 ^a 0.0 ^a 6.6 ^a	52.3 48.3 36.7
Rodríguez-Santillán (40) Borregos Pelibuey x Rambouillet	-49.2% <i>M. sativa</i> + 50.8% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral -32.8% <i>Pithecellobium pallens</i> + 67.2% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral -62.4% <i>Parkinsonia aculeata</i> + 37.6% paja de zacate estrella + 5% melazas + 0.5% premezcla mineral	55.3 53.3 58.6	28.7 24.8 27.4	17.3 20.7 22.8	8.0 5.8 7.0	0.0 0.0 1.4	54.5 45.5 49.8
Moreno-Villanueva (41) Borregos Pelibuey x Rambouillet	-23% <i>M. sativa</i> + 77% paja de zacate bermuda + 5% de melazas + 0.5% premezcla mineral -26.3% <i>Acacia greggii</i> + 70.7% paja de zacate bermuda + 5% de melazas + 0.5% premezcla mineral -14.3% <i>Prosopis glandulosa</i> + 76.3% paja de zacate bermuda + 5% de melazas + 0.5% premezcla mineral	62.5 59.1 66.4	28.9 27.7 30.0	18.4 20.4 16.3	5.5 7.6 6.5	0.0 ^a 0.0 ^a 0.0 ^a	40.9 40.6 38.6
Ramírez y Ledezma-Torres (42) Cabras Españolas	-23% <i>Medicago sativa</i> + 77% paja de frijol -25% <i>Acacia rigidula</i> + 75% paja de frijol -20% <i>Acacia farnesiana</i> + 80% paja de frijol	52.3 50.1 50.1		13.4 8.1 11.4		0.2 18.0 1.8	55.7 48.5 43.7
García-Castillo et al. (43) Borregos Pelibuey x Rambouillet	-41.4% <i>M. sativa</i> + 53.1% rastrojo de maíz + 5% melazas + 0.5% premezcla mineral -30.6% <i>Leucaena leucocephala</i> + 63.9% rastrojo de maíz + 5% melazas + 0.5% premezcla mineral -37.7% <i>Acacia berlandieri</i> + 56.8% rastrojo de maíz + 5% melazas + 0.5% premezcla mineral	50.2 55.5 59.5	24.5 24.8 26.3	19.9 25.0 27.2	4.8 4.1 5.0	0.2 ^a 1.9 ^a 4.5 ^a	55.7 46.2 39.9
Ramírez y Lara (44) Borregos Pelibuey x Rambouillet	-26% <i>M. sativa</i> + 74% paja de buffel + 400 g.día grano de sorgo y melazas -30% <i>A. rigidula</i> + 70% paja de buffel + 400 g.día grano de sorgo y melazas -16% <i>Cercidium macrum</i> + 84% paja de buffel + 400 g.día grano sorgo y melazas -21% <i>A. farnesiana</i> + 79% paja de buffel + 400 g.día grano sorgo y melazas	68.0 67.1 67.9 64.5		30.2 28.6 25.8 26.7	3.5 5.7 3.0 4.1	0.2 14.8 4.0 1.8	47.5 39.0 45.9 46.5
Ramírez (45) Cabras Españolas	-23% <i>M. sativa</i> + 77% paja de frijol -22% <i>Celtis pallida</i> + 78% paja de frijol -18% <i>Leucophyllum texanum</i> + 18% <i>Porlieria angustifolia</i> + 64% paja de frijol	57.3 52.6 51.1		16.3 13.8 12.8	3.9 3.9 4.0	0.2 0.3 0.4	56.9 48.0 46.2
Ramírez et al. (46) Cabras Españolas	-23% <i>M. Sativa</i> + 77% paja de frijol -13% <i>C. macrum</i> + 87% paja de frijol -100% paja de frijol	58.3 59.5 60.6		14.5 21.2 14.5	3.8 6.5 4.9	0.02 3.9 0.7	49.1 48.9 36.2

DIVPC = digestibilidad in vivo de la pared celular

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**Kinetics of dry matter digestion in leaves of native shrubs from the Sonoran desert
México**

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Table 1. A
degradabi

Introduction

Quantitative expressions of the kinetics of digestion and passage are needed to precisely estimate the quantity and composition of nutrients digested from forages, and the subsequent efficiency of utilization by the animal. Furthermore, the measurement of immediately soluble matter, insoluble but potentially degradable matter and rate of dry matter degradation using nylon bags are good predictors of intake in ruminants (Forbes, 1995). The objectives of this study were to estimate and compare the extent and rate of dry matter digestion from leaves of native shrubs from the arid region of Baja California Sur, México.

Materials and Methods

Branches from the legumes *Acacia peninsularis* (Britt. L. Rose) Standley, *Cercidium floridium* (Benth) *Pithecellobium confine* (Standley), *Prosopis* sp. (Torr) and *Bursera microphylla* Gray (Burseraceae), *Turnera difusa* Willd (Turneraceae), *Cyrtocarpa edulis* (Brand) Standley (Anacardiaceae), *Mimosa xantii*, Gray (Mimosaceae), *Lippia palmeri*, S. Wats (Verbenaceae) and *Opuntia cholla*, Weber (Cactaceae) were collected from 16 linear transects of 30 m, located randomly. Collections were carried out in the four seasons of 1993; Winter (February 23), Spring (May 23), Summer (August 23) and Fall (November 23). In each season, branches were bulked in one sample of each species and were allowed to dry under shed. Leaves from branches were removed manually and ground in a Wiley mill (2-mm screen). In this study the alfalfa hay (*Medicago sativa*) was included as a reference plant. In each season, duplicate samples were used to estimate the rate (kd , %/h) and extent of DM loss from nylon bags (50 µm pore size) using four ruminally cannulated steers (250 ± 5.3 kg body weight). During the trial steer were fed alfalfa hay (16% CP). Plant material (4 g) was placed in nylon bags and suspended in the rumen of steers for 1, 2, 3, 4, 8, 12, 24, 48, 72 and 100 hours (h). Zero-time disappearance (a fraction, %) was determined from unincubated bags. The DM digestion characteristics of plants were calculated (Ørskov and McDonald, 1979) using the equation: $p = a + b(1 - e^{-kd \cdot t})$ and effective degradability of DM (EDDM) was calculated assuming a rumen outflow rate (k) of 5%/h using the equation: $EDDM = a + b \cdot kd / (kd + k) \cdot e^{-kd \cdot t}$. Annual means were statistically analyzed by one-way analysis of variance. Simple linear correlation analysis was performed between chemical analysis and rate of digestion and EDDM of plants (Steel and Torrie, 1980).

Results and Discussion

Annual mean of fraction a was significantly different among plants (Table 1). *Prosopis* sp. had the highest value, but *L. palmeri* was lowest. Annual mean of fraction slowly degraded in the rumen of steers (b , %) was also significantly different among plants. *Lippia palmeri* resulted with the highest percentage, but *P. confine* was lowest. Annual mean of fraction of DM potentially degraded in the rumen ($a+b$, %) of steers was highest in *C. floridum*, however, *P. confine* was lowest. Significantly differences were detected in $a+b$ percentage (Table 1). The kd

Pla
Medicago
Acacia pe.
Bursera m.
Cercidium
Cyrtocarp
Lippia pa
Mimosa x
Opuntia c
Pithecelli
Prosopis
Turnera

Mean
Standard
Significa

a = Fra
degrad
 kd = fr
of DM

Referenc
Forbes, J
Internat
Ørskov, I
Steel R.C
Hill, N

significantly different among plants. All shrubs species had lower rate of DM digestion than *M. sativa*. Among shrubs, *L. palmeri* was highest and *A. peninsularis* was lowest. With exception of *O. cholla*, all shrubs species had lower EDDM than *M. sativa*. *Medicago sativa* resulted with lowest lag time (h). On the other hand, *M. xantii* had the highest lag time (Table 1).

The lignin content was negatively correlated with *kd* ($r = -.43, P < .001$) and EDDM ($r = -.47, P < .001$). Similarly the tannin content was negatively correlated with *kd* ($r = -.59, P < .001$) and EDDM ($r = -.52, P < .001$). It is concluded that lignin and condensed tannins in the evaluated plants may limit the dry matter extent and rate of degradation.

Table 1. Annual mean of nonlinear parameters of digestibility and effective degradability of dry matter in shrub leaves and alfalfa hay.

Plants ¹	a (%)	b (%)	a+b (%)	kd (%/h)	EDDM (%)	Lag time (h)
<i>Medicago sativa</i>	36.6	36.9	73.5	14.8	63.1	0.7
<i>Acacia peninsularis</i>	32.3	37.8	70.2	4.1	49.1	2.2
<i>Bursera microphylla</i>	33.5	32.8	66.3	9.9	55.4	1.2
<i>Cercidium floridum</i>	33.9	46.2	80.2	6.9	60.0	1.4
<i>Cyrtocarpa edulis</i>	32.0	33.0	65.1	4.2	45.5	1.8
<i>Lippia palmeri</i>	19.7	51.2	70.9	12.4	56.1	1.7
<i>Mimosa xantii</i>	34.2	33.2	67.4	2.7	45.8	3.3
<i>Opuntia cholla</i>	39.8	34.0	73.9	10.2	63.0	2.5
<i>Pithecellobium confine</i>	30.5	22.8	53.3	4.3	40.0	2.5
<i>Prosopis sp</i>	40.3	28.6	69.0	9.6	59.5	1.5
<i>Turnera difusa</i>	21.6	41.0	62.7	11.0	49.8	1.5
Mean	32.3	36.0	68.3	8.2	53.4	1.9
Standard error	1.6	2.7	2.6	1.4	1.9	0.4
Significance	***	***	***	***	***	***

¹*a* = Fraction of dry matter (DM) lost during wash; *b* = fraction of DM slowly degraded in the rumen; *a+b* = fraction of DM potentially degraded in the rumen; *kd* = fractional rate of degradation of the DM; EDDM = effective degradability of DM calculated for 5%/h passage rate; ***($P < 0.001$).

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In vitro volatile fatty acids concentration in leaves of native shrubs from the Sonoran desert of México

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Introduction

Fiber digestibility is usually defined as the proportion of ingested fiber not excreted in the feces. The process of fiber digestion contains two major events, hydrolysis of polysaccharides and conversion of monosaccharides to volatile fatty acids (VFA). Methane, fermentation gases, and heat (Tamminga, 1993). The losses of energy in methane and heat during fermentation can be significant. Measurements of the concentrations and amounts of VFAs are an important part of ruminant nutrition because the VFAs produced as end products of anaerobic microbial metabolism provide the ruminant with a major source of metabolizable energy (Van Soest, 1994). This study was conducted to estimate and compare the in vitro VFAs production from leaves of ten native plants from a shrubland of Baja California Sur, México.

Materials and Methods

Branches from the legumes *Acacia peninsularis* (Britt. L. Rose) Standley, *Cercidium floridum* (Benth) *Pithecellobium confine* (Standley), *Prosopis* sp. (Torr) and *Bursera microphylla* Gray (Burseraceae), *Turnera difusa* Willd (Turneraceae), *Cyrtocarpa edulis* (Brand) Stand (Anacardiaceae), *Mimosa xanti*, Gray (Mimosaceae), *Lippia palmeri*, S. Wats (Verbenaceae) and *Opuntia cholla*, Weber (Cactaceae) were collected from 16 linear transects of 30 m, located randomly. Collections were carried out in the four seasons of 1993; Winter (February 23), Spring (May 23), Summer (August 23) and Fall (November 23). In each season, branches were bulked in one sample of each species and were allowed to dry under shade. Leaves from branches were removed manually and ground in a Wiley mill (2-mm screen). In this study the alfalfa hay (*Medicago sativa*) was included as a reference plant. In each season, duplicate samples were subjected to determine in vitro VFAs concentration. Batch culture in vitro procedure was used with McDougall's artificial saliva. The inoculum was obtained from a mixed ruminal content of four ruminal cannulated steers. Steers were fed alfalfa hay (16% CP). The procedure was as described by Ramírez et al. (1997). After the incubation tubes were centrifuged, the resulting supernatant fraction was analyzed for VFAs by chromatography (Goetsch and Galyean, 1983). Total concentration (mM) of acetate, propionate and butyrate were calculated by adjusting forage cultures for the total VFAs concentration from appropriate blank culture. The significance of plant effects on the annual means of in vitro VFAs concentrations were determined by one-way analysis of variance. Correlation analysis was performed between chemical analysis and concentration of each VFAs of plants (Steel and Torrie, 1980).

Results and Discussions

Annual means of total VFAs, acetate, propionate and butyrate (mM) were significantly different ($P<0.001$) among evaluated plants (Table 1). Annual means of total

VFAs was higher in *C. floridum* had comparable values observed in the annual mean. Similar propionate concentrations were lower than *M. sativa*. It seems that VFAs concentration is higher in leaves from most plants than *M. sativa*.

Table 1. Annual means of in vitro VFAs of plants and alfalfa hay.

	Plants
<i>Medicago sativa</i>	
<i>Acacia peninsularis</i>	
<i>Bursera microphylla</i>	
<i>Cercidium floridum</i>	
<i>Cyrtocarpa edulis</i>	
<i>Lippia palmeri</i>	
<i>Mimosa xanti</i>	
<i>Opuntia cholla</i>	
<i>Pithecellobium confine</i>	
<i>Prosopis</i> sp	
<i>Turnera difusa</i>	
Mean	
Standard error	
Significance	

¹Total VFAs= Total VFAs

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VFAs was higher in *O. choya* than *M. sativa*, but *A. peninsularis* was lowest. *Cercidium floridum* had comparable total VFAs concentration than *M. sativa*. The same pattern was observed in the annual mean of acetate. *Prosopis sp.* resulted with higher and *O. cholla* had similar propionate concentrations than *M. sativa*. *Acacia peninsularis* also resulted with lowest propionate concentration. In this study, all shrubs had lower butyrate concentrations than *M. sativa*. It seems that lignin and condensed tannins in leaves of shrubs limited total VFAs concentration ($r=-0.34$ and $r=-0.28$, respectively). Ramirez et al. (1997) also reported that leaves from most of the 10 shrubs that grow in northeastern México had lower total VFAs than *M. sativa*.

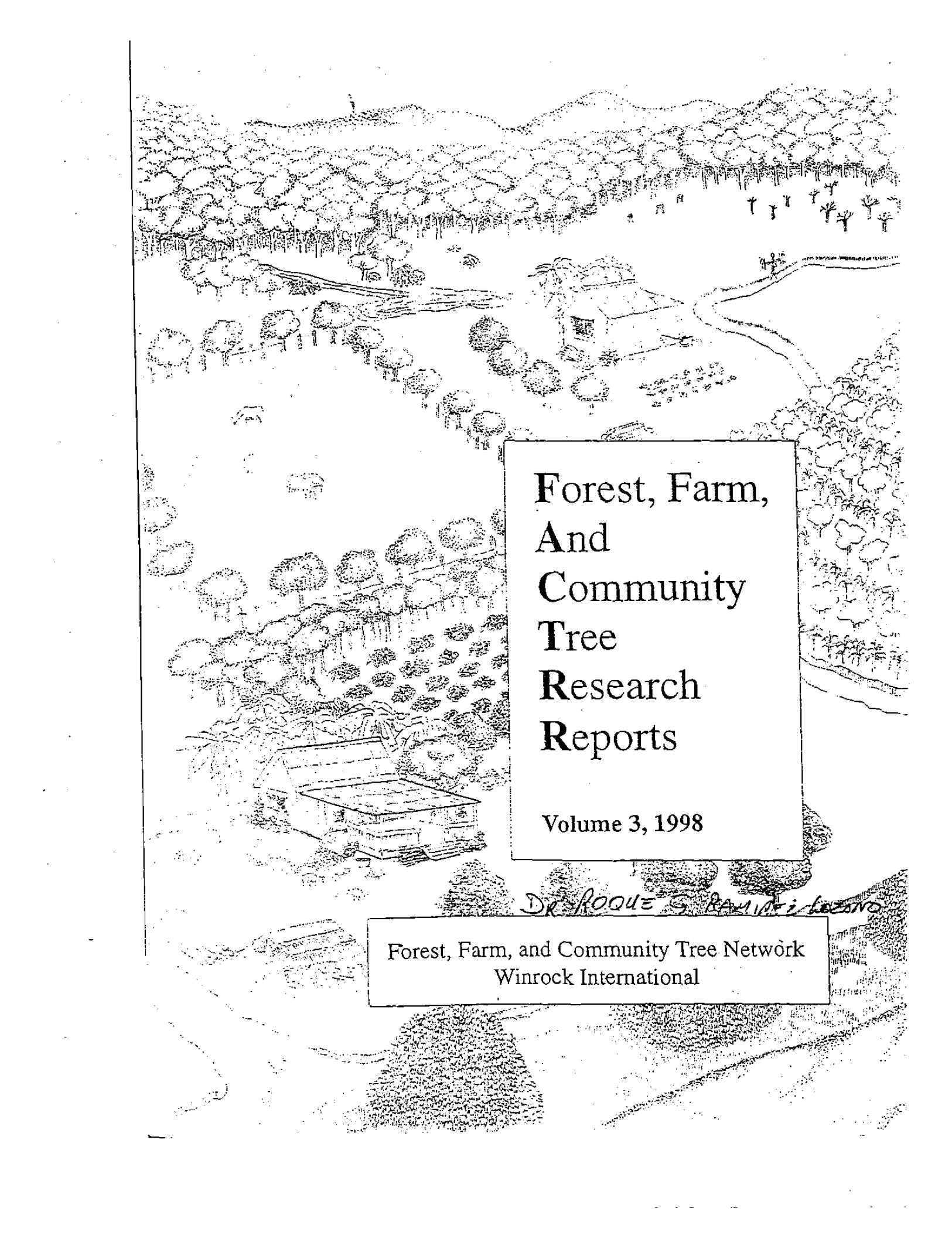
Table 1. Annual means (mM) of in vitro volatile fatty acids concentration in shrub leaves and alfalfa hay.

Plants	Total VFAs ¹	Acetic acid	Propionic acid	Butyric acid
<i>Medicago sativa</i>	72.1	52.7	13.0	6.2
<i>Acacia peninsularis</i>	49.5	37.9	8.4	3.1
<i>Bursera microphylla</i>	58.5	43.4	10.6	4.5
<i>Cercidium floridum</i>	72.3	52.8	11.8	4.3
<i>Cyrtocarpa edulis</i>	65.2	52.4	9.0	3.8
<i>Lippia palmeri</i>	61.5	47.6	8.9	4.4
<i>Mimosa xantii</i>	61.7	48.7	9.9	3.0
<i>Opuntia cholla</i>	76.9	59.0	13.2	5.1
<i>Pithecellobium confine</i>	58.1	44.3	9.5	3.9
<i>Prosopis sp</i>	69.9	51.1	15.4	3.4
<i>Turnera difusa</i>	55.8	42.1	9.1	3.7
Mean	63.8	48.3	10.8	4.1
Standard error	4.6	3.5	0.7	0.7
Significance	***	***	***	***

¹Total VFAs= Total volatile fatty acids; ***($P<.001$).

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Seasonal variation in leaf mineral content of shrubs from Baja California Sur, Mexico

In many areas of the world, the nutritional status of grazing animals represents one of the main problems that limit animal production, and the main factors are low protein content of the forages, low energy intake because of high fiber content, and vitamin and mineral deficiencies (García and Montemayor 1987).

To understand the adequate mixture of required minerals to satisfy animals' needs, one must take account the mineral content in forages, water, and soil (Underwood 1981). However, Sousa (1978) asserted that mineral analysis of soil is not a precise tool for assessing the mineral nutrition of the animals that graze vegetation growing in the soil, because the soil mineral profile did not reveal possible animal deficiencies. Moreover, minerals in water and soil could provide adequate amounts of Co, Zn, Ca, P, and Fe, but P, Mg, Ca, and Cu could interfere with the absorption of the other minerals (García and Montemayor 1987). Minerals in the foliage can be an effective means to predict the possible mineral status of the grazing animals consuming that foliage, but changes in climate may affect the mineral composition and availability in foliage (McDowell 1997). Our study evaluated and compared seasonal variation in the mineral composition of 10 native shrubs that grow in Baja California Sur, Mexico.

Materials and methods

The study was done in the ranch Palmar de Abajo (800 ha) located in La Paz Baja California Sur ($23^{\circ}38'40''N$, $110^{\circ}18'07''W$). The climate of the region is arid with annual mean temperature of $22^{\circ}C$ and precipitation of 182 mm; the rainy season occurs during the summer and winter months. Branches from the legumes *Acacia peninsularis* (Britt. L. Rose) Standley, *Cercidium floridum* (Benth.) *Pithecellobium confine* (Standley), and *Prosopis* sp. (Torr.) and the non-legumes *Bursera microphylla* Gray (Burseraceae), *Turnera difusa* Willd. (Turneraceae), *Cyrtocarpa edulis* (Brand) Stand. (Anacardiaceae), *Mimosa xantii*, Gray (Mimosaceae), *Lippia palmeri*, S. Wats (Verbenaceae), and *Opuntia cholla*, Weber (Cactaceae) were collected from 16 linear transects of 30 m, located randomly. Collections were made in the four seasons of 1993; winter (Feb. 23), spring (May 23), summer (Aug. 23), and fall (Nov. 23). In each season, branches were bulked in one sample of each species and were allowed to dry under a shed. Leaves were manually removed from the branches and ground in a Wiley mill (2-mm screen). Shrubs evaluated in this study are reported to be consumed by cattle and goats (Agúndez et al. 1992, Arreaga and Cancino 1992).

In each season, triplicate samples of leaves from each shrub were prepared for mineral analysis using the wet ashing ($HCl-HNO_3$) procedure of AOAC (1990). Atomic absorption spectrophotometry using an air-acetylene flame was used to measure mineral concentrations of Ca, Mg, Na, K, Ca, Fe, Zn, and Mn. Phosphorous concentration was measured by colorimetry (AOAC 1990). The significance of plant effects on mineral composition

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was determined by analysis of variance using a completely randomized block design. The seasons were the blocks and plants were the treatments (Statistix 1996).

Results and discussion

Higher concentrations of P in leaves of shrubs were found in summer and winter seasons than in other seasons. With the exception of *M. xantii*, all shrubs had concentrations of P that were significantly different among seasons (Table 1). *Lippia palmeri* had the highest (annual mean) concentration of P, and *P. confine* had the lowest. Phosphorus requirements in the diet of grazing beef cattle are from 1.8 to 3.8 g/kg (NRC 1996).

In this study, most shrubs in all seasons had concentrations of Ca in sufficient amounts to meet beef cattle requirements (1.9 to 7.3 g/kg; NRC 1996). *Opuntia cholla* had the highest level of Ca, and *M. xantii* had the lowest.

During the summer, most shrubs had high levels of Mg (Table 1), but during the spring and winter seasons, they were low. *Opuntia cholla* had the highest level of Mg, and *T. difusa* had the lowest. Only *C. edulis*, *O. cholla*, and *Prosopis* sp. were significantly different ($P < 0.05$) among seasons. It seems that all shrubs in all seasons had enough Mg to meet grazing beef cattle requirements (1.0 g/kg; NRC 1996).

During spring and summer, most shrubs had higher Na concentrations than at other times (Table 2). All shrubs, with the exception of *B. microphylla* and *O. cholla*, were significantly different among seasons in their Na concentration. In all seasons, shrubs such as *A. peninsularis*, *O. cholla*, and *Prosopis* sp. had Na levels below beef cattle requirements (0.6 to 0.8 g/kg; NRC 1996).

During winter and summer, most shrubs had higher levels of K than at other times (Table 2). Most shrubs were significantly different among seasons in their K concentrations; only *M. xantii* and *T. difusa* in the spring had levels of K too low to meet beef cattle requirements (6.0 g/kg; NRC 1996). During spring and winter, most plants had high Zn concentrations, whereas during other seasons they were low (Table 2). All the shrubs had levels of Zn that were significantly different among seasons. Grazing beef cattle require about 30 mg/kg of Zn in their diet (NRC 1996), and in all seasons, all shrubs studied had insufficient Zn to meet cattle requirements.

During winter and summer, the shrubs had higher concentrations of Cu than in other seasons (Table 3). Moreover, most plants had Cu concentrations that were significantly different among seasons, with the exception of *A. peninsularis*, *C. floridum*, *C. edulis*, and *T. difusa*, which were not different ($P < 0.05$). Grazing beef cattle require around 10 mg/kg of Cu in their diets to satisfy requirements. In this study, only plants such as *B. microphylla*, *L. palmeri*, and *T. difusa* had, during spring, summer, and winter, sufficient amounts of Cu to meet cattle requirements (NRC 1996).

All plants in all seasons had sufficient concentrations of Fe (50 mg/kg; NRC 1996) to meet the requirements of grazing beef cattle. Most shrubs had high Fe concentrations during spring but low levels during winter and fall (Table 3). Moreover, all shrubs, with the exception of *Prosopis* sp., had levels of Fe that were significantly different among seasons.

All shrubs in all seasons had Mn concentrations in their leaves adequate to meet grazing beef cattle requirements (20 mg/kg; NRC 1996). Moreover, during spring and summer, most shrubs had high Mn concentrations, but during winter and fall they were low. All plants had Mn levels that were significantly different among seasons (Table 3).

Conclusions

Mineral concentrations of all the shrubs tested varied seasonally. P, Ca, K, Mg, and Fe were present in leaves of the shrubs in sufficient amounts to meet grazing beef cattle requirements. Na, Zn, and Cu concentrations were below cattle requirements.

Table 1. Seasonal ranges of P, Ca, and Mg (g/kg dry matter) in the leaves of shrubs.

Plants	P				Ca				Mg			
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig
<i>Acacia pennsylvanica</i>	2 f - 4 w	3	0.2	**	9 w - 17 t	15	0.8	**	2 w - 9 sp	4	1.1	NS
<i>Bursera microphylla</i>	2 w - 3 f	3	0.2	**	17 su - 23 w	19	2.0	NS	2 sp - 5 su	4	0.7	NS
<i>Cercidium floridum</i>	2 f - 3 sp	3	0.1	***	15 su - 30 t	24	1.2	***	3 sp - 9 f	6	1.3	NS
<i>Cyrtocarpa edulis</i>	2 f - 3 sp	3	0.1	**	17 f - 27 sp	20	2.4	*	2 w - 5 sp	3	0.4	***
<i>Lippia palmeri</i>	3 f - 5 sp	4	0.6	*	19 su - 23 w	21	1.3	NS	2 f - 6 su	4	0.6	NS
<i>Mimosa xanti</i>	2 sp - 4 su	3	0.1	NS	11 sp - 12 w	11	0.9	NS	2 su - 5 w	4	0.8	NS
<i>Opuntia cholla</i>	2 sp - 3 su	2	0.2	***	22 f - 46 su	40	1.5	***	10 f - 17 su	13	0.8	**
<i>Pithecellobium confine</i>	2 su - 2 w	2	0.1	**	19 f - 24 sp	20	1.9	NS	3 w - 5 f	4	0.8	NS
<i>Prosopis</i> sp.	1 f - 4 w	3	0.4	**	14 w - 28 su	20	0.9	***	3 w - 4 su	4	0.3	*
<i>Turnera diffusa</i>	2 f - 3 w	3	0.3	***	10 sp - 15 su	13	1.1	*	2 sp - 3 su	3	0.5	NS

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; f = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

Table 2. Seasonal ranges of Na, K (g/kg dry matter), and Cu (mg/kg dry matter) in the leaves of shrubs.

Plants	Na				K				Zn			
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig
<i>Acacia pennsylvanica</i>	0.2 su - 0.8 sp	0.4	0.1	***	10 sp - 12 su	11	2.1	NS	12 sp - 19 w	15	0.8	**
<i>Bursera microphylla</i>	0.9 su - 3.2 sp	1.7	0.5	NS	10 w - 12 f	11	0.9	NS	14 w - 22 sp	18	0.7	**
<i>Cercidium floridum</i>	0.7 su - 1.4 sp	1.0	0.1	***	10 f - 16 w	13	0.5	**	20 sp - 22 su	21	0.1	**
<i>Cyrtocarpa edulis</i>	0.4 su - 1.3 f	0.8	0.1	***	9 w - 11 w	9	1.1	NS	14 w - 17 w	16	0.6	*
<i>Lippia palmeri</i>	0.9 sp - 1.2 su	1.0	0.01	***	15 sp - 19 w	17	0.9	*	13 sp - 22 su	18	0.2	***
<i>Mimosa xanti</i>	0.2 w - 0.8 f	0.6	0.05	***	4 sp - 11 su	8	0.5	***	11 w - 19 su	14	0.2	***
<i>Opuntia cholla</i>	0.3 w - 0.8 sp	0.6	0.04	***	17 sp - 24 su	21	1.9	**	9 sp - 18 su	13	0.3	***
<i>Pithecellobium confine</i>	0.2 w - 0.9 su	0.5	0.02	***	8 f - 13 su	11	0.5	*	18 f - 28 w	22	0.2	***
<i>Prosopis</i> sp.	0.6 sp - 0.9 su	0.7	0.02	***	9 su - 14 w	11	0.5	*	19 sp - 25 su	22	0.6	**
<i>Turnera diffusa</i>					3 sp - 10 w	7	0.4	***				

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; f = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

Table 3. Seasonal ranges of Cu, Fe, and Mn (mg/kg dry matter) in the leaves of shrubs.

<i>Mimosa xanthii</i>	0.2	0.0	0.6	0.3	0.06	NS	17	SP	8	f	-	13	SU	11	0.5	**	18	I	-	28	W	22	0.2	**
<i>Opuntia cholla</i>	0.1	I	-	0.6	0.04	**																		
<i>Pithecellobium confine</i>	0.3	W	-	0.8	0.6	0.04	**																	
<i>Prosopis</i> sp.	0.2	W	-	0.9	0.5	0.02	***																	
<i>Turmera diffusa</i>	0.6	SP	-	0.9	0.7	0.02	***																	

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; I = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

Table 3. Seasonal ranges of Cu, Fe, and Mn (mg/kg dry matter) in the leaves of shrubs.

Plants	Cu						Fe						Mn											
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig								
<i>Acacia peninsulae</i>	8	W	-	9	SP	9	0.6	NS	83	SU	-	305	f	194	8	***	29	W	-	45	f	39	0.9	***
<i>Bursera microphylla</i>	5	W	-	11	SP	8	0.8	**	98	SU	-	337	SP	195	12	***	52	f	-	116	SP	78	1.6	***
<i>Cercidium floridum</i>	5	SP	-	7	W	6	0.2	NS	166	SU	-	360	SP	232	3	***	44	SU	-	117	W	72	1.6	***
<i>Cyrtocarpa edulis</i>	5	SP	-	7	W	6	1.1	NS	184	W	-	357	SP	271	8	***	24	SU	-	41	SP	34	1.4	***
<i>Lippia palmeri</i>	6	SP	-	11	SU	9	0.2	***	142	W	-	523	f	345	2	***	46	SU	-	54	SP	49	0.6	***
<i>Mimosa xanthii</i>	4	SP	-	8	SU	6	0.5	**	141	W	-	862	SU	430	6	***	36	I	-	51	W	46	1.8	**
<i>Opuntia cholla</i>	4	SP	-	8	SU	5	0.4	***	79	f	-	184	SP	139	8	**	46	f	-	201	SP	141	4.1	***
<i>Pithecellobium confine</i>	5	SU	-	7	W	6	0.1	***	105	SU	-	269	SP	182	16	**	35	SU	-	42	SP	40	0.6	***
<i>Prosopis</i> sp.	4	SP	-	7	W	5	0.2	**	128	f	-	172	SP	151	19	NS	65	W	-	127	SU	87	4.1	***
<i>Turmera diffusa</i>	8	I	-	11	W	9	1.6	NS	336	f	-	438	W	376	15	*	76	f	-	97	SU	89	2.8	**

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; I = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

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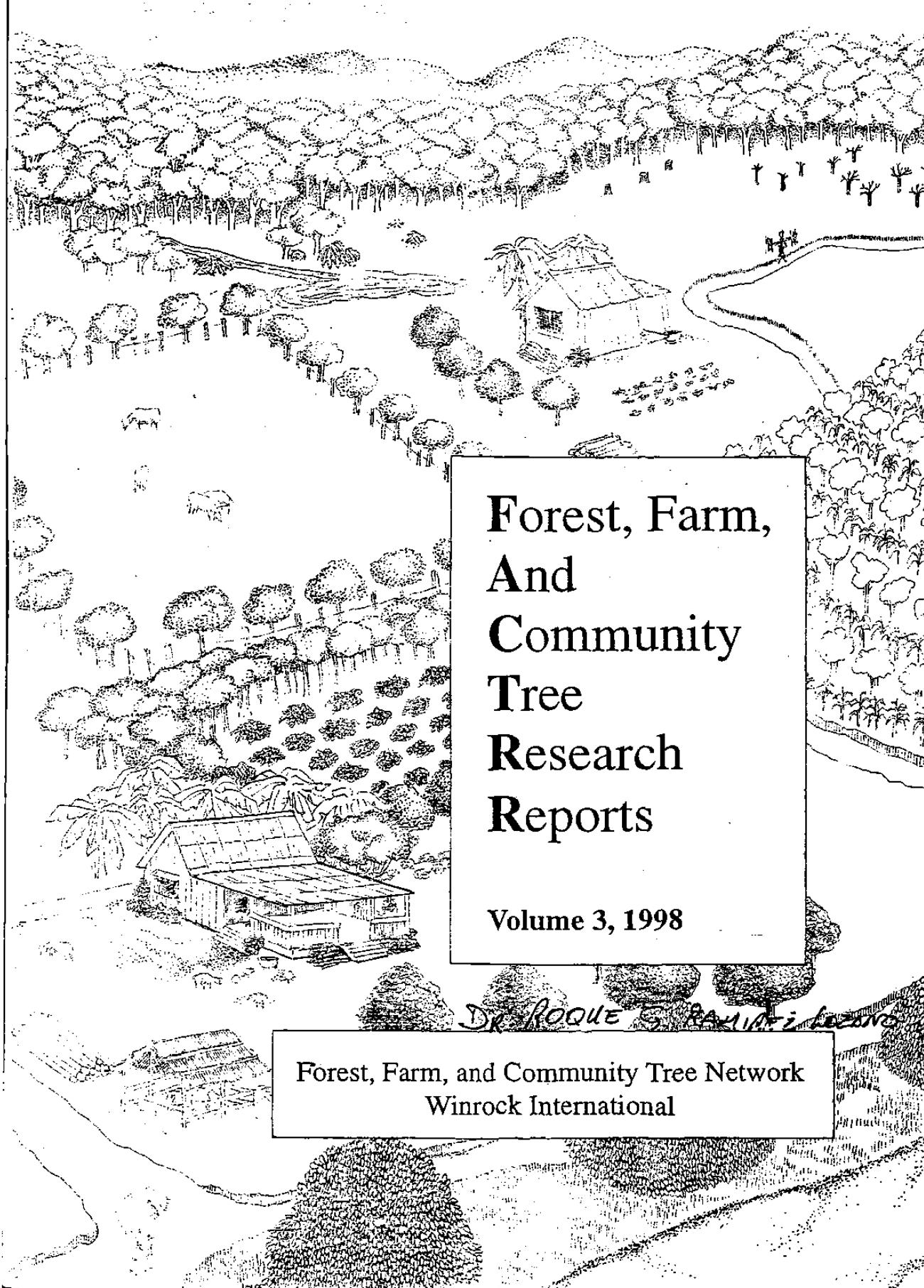
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Forest, Farm, And Community Tree Research Reports

Volume 3, 1998

Dr. ROQUE S. RAMOS, *Editor*

Forest, Farm, and Community Tree Network
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R. Ramírez-Orduña¹, R. G. Ramírez², J. M. Ramírez-Orduña¹, R. Cepeda-Palacios¹, and J.M. Avila-Sandoval¹. ¹Departamento de Zootecnia, Universidad Autónoma de Baja California Sur. ²Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Nuevo León. Apartado Postal 142, Sucursal F, San Nicolás de los Garza, N.L. 66451, Mexico.

Seasonal variation in nutrient content of shrubs from Baja California Sur, Mexico

Shrubs are an important source of nutrients for ruminants in arid and semiarid regions. Leguminous plants are important because of their ability to fix nitrogen, and they often are well suited as animal feeds (Devendra 1995). Grazing ruminants have developed the ability to use these plants as the only source of nutrients; however, the lignin in plants protects the structural carbohydrates of plants from microbial digestion (Van Soest 1994). Moreover, cell wall represents 35–80 percent of the organic matter (Jung and Allen 1995) and 30–40 percent of the digestible energy intake (Galleyan and Goetsch 1993).

In the peninsula of Baja California, an arid region of Mexico, shrubs are heavily consumed by livestock, and most of these plants are legumes. This study was conducted to compare by season the nutrient profile of 10 native shrubs that grow there.

Materials and methods

The study was done in the ranch Palmar de Abajo (800 ha) located in La Paz, Baja California Sur (23°38'40"N, 110°18'07"W). The climate of the region is arid with annual mean temperature of 22°C and precipitation of 182 mm; the rainy season occurs during the summer and winter months. Branches from the legumes *Acacia peninsularis* (Britt. L. Rose) Standley, *Cercidium floridum* (Benth.) *Pithecellobium confine* (Standley), and *Prosopis* sp. (Tort.) and the non-legumes *Bursera microphylla* Gray (Burseraceae), *Turnera difusa* Willd. (Turneraceae), *Cyrtocarpa edulis* (Brand) Stand. (Anacardiaceae), *Mimosa xantii*, Gray (Mimosaceae), *Lippia palmeri*, S. Wats (Verbenaceae), and *Opuntia cholla*, Weber (Cactaceae) were collected from 16 linear transects 30 m long at random locations. Collections were made in the four seasons of 1993: winter (February 23), spring (May 23), summer (August 23), and fall (November 23). In each season, branches were bulked in one sample of each species and dried under a shed. Leaves were manually removed from the branches and ground in a Wiley mill (2-mm screen). Alfalfa hay (*Medicago sativa*) was included as reference plant with high CP content. Shrubs evaluated in this study are reported to be consumed by cattle and goats (Agundes et al. 1992, Arreaga and Cancino 1992). In each season, duplicate samples were analyzed to determine dry matter (DM), ash, crude protein (CP), lignin (AOAC 1990), neutral detergent fiber (NDF), acid detergent fiber (ADF, Goering and Van Soest 1970 modified by Van Soest et al. 1991), and condensed tannins (Burns 1971 modified by Price et al. 1978). The significance of plant effects on nutrient composition was determined by analysis of variance using a completely randomized block design. The seasons were the blocks and plants were the treatments (Statistix 1996).

Results and discussion

Table 1 shows the ranges and annual means of organic matter (OM), CP, and ash. The OM percentage in most plants was significantly different among seasons, except for *L. palmeri*, *P. confine*, and *Prosopis* sp. With exception of *O. cholla*, all shrubs had higher OM (annual

mean) than *M. sativa*. CP content was higher in winter and lower in spring for most plants. With the exception of *P. confine*, the shrubs were significantly different in CP content among seasons. Only *P. confine* and *Prosopis* sp. had higher CP (annual mean) than *M. sativa*. It has been reported that in general the CP in browse species is high and varies from 11.1 to 41.7 (Ramírez, 1996). In our study, however, *O. cholla*, *B. microphylla*, *L. palmeri*, and *T. difusa* had very low CP values in all seasons of the year.

Cell wall, ADF (ligno-cellulose), and cellulose contents are shown in Table 2. During spring and winter, most shrubs had higher cell wall percentage than in other seasons. With the exception of *C. floridum*, *P. confine*, and *Prosopis* sp., all shrubs were significantly different among seasons. On the other hand, ADF values were higher during the fall and spring. All shrubs had significantly different ADF values among seasons. The cellulose content was significantly different among seasons only in *A. peninsularis*, *B. microphylla*, *C. floridum*, *C. edulis*, and *P. confine*. All the shrubs had higher cellulose content (annual mean) than *M. sativa*.

Only *O. cholla* had higher hemicellulose values (annual mean) than *M. sativa*. Most shrubs had higher hemicellulose content in winter (Table 3), and most had hemicellulose percentages that were significantly different among seasons. In general, annual mean percentages of hemicellulose were lower than cellulose. This finding also was reported by Norton and Poppi (1995). In spring and fall, most shrubs had higher levels of lignin than in other seasons. All shrubs except *B. microphylla* were significantly different among season in their lignin contents (Table 3). Lignin was high in most shrubs compared to *M. sativa*. It has been reported that, in general, browse plants have lower lignin than grasses (Norton and Poppi 1995). It also has been reported that high levels of lignin negatively affect the rate and extent of dry matter digestion in shrubs from northeastern Mexico. (Ramírez et al. 1998). Most plants had higher condensed tannins during fall and winter than in other seasons (Table 3). All shrubs had higher levels of condensed tannins than *M. sativa*.

Conclusions

All of the nutritional factors analyzed in the leaves of these shrubs varied seasonally. Higher values of CP and hemicellulose were found in winter. Most of the shrubs had high levels of lignin, and in *L. palmeri*, *P. confine*, and *B. microphylla*, lignin was about 40 percent of the cell wall content.

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Crude protein

Ash

Organic matter

Table 1. Seasonal ranges of the organic matter, ash, and crude protein contents (% of DM) in the leaves of shrubs.

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Table 1. Seasonal ranges of the organic matter, ash, and crude protein contents (% of DM) in the leaves of shrubs.

Plant	Organic matter					Ash					Crude protein				
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig			
<i>Medicago sativa</i>	89	0.11	**		5 w - 7 sp	6	0.1	***	11 f - 20 w	13	1.6	**			
<i>Acacia penninsularis</i>	92 sp - 95 w	94	0.11	**	7 f - 9 w	8	0.2	**	5 sp - 10 w	8	0.4	**			
<i>Bursera microphylla</i>	91 w - 93 f	92	0.21	**	8 su - 11 f	10	0.4	**	13 sp - 21 w	15	0.5	***			
<i>Cercidium floridum</i>	89 f - 92 su	91	0.41	***	7 su - 9 w	8	0.4	*	10 sp - 16 w	13	0.4	***			
<i>Cyrtocarpa edulis</i>	90 w - 93 su	92	0.46	**	9 sp - 11 w	10	0.5	NS	7 sp - 12 w	9	0.3	***			
<i>Lippia palmeri</i>	89 w - 91 sp	92	0.51	NS	5 w - 7 su	6	0.4	***	11 sp - 17 w	15	0.6	**			
<i>Mimosa xantii</i>	93 su - 95 w	94	0.43	*	7 w - 9 su	14	0.1	*	3 sp - 6 w	4	0.3	**			
<i>Opuntia cholla</i>	81 su - 93 w	86	0.14	***	7 w - 9 sp	8	0.5	***	12 su - 24 w	17	1.3	NS			
<i>Pithecellobium conifine</i>	91 sp - 93 f	92	0.55	NS	6 w - 8 su	7	0.4	NS	16 f - 26 w	19	2.0	*			
<i>Prosopis sp.</i>	92 su - 94 w	93	0.45	NS	6 f - 15 w	9	0.1	NS	6 sp - 13 su	10	0.6	**			
<i>Turnera diffusa</i>	85 w - 94 sp	91	0.13	**	6 f - 15 w	9	0.1	NS	11 sp - 17 w	15	0.6	**			

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; f = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

Table 2. Seasonal ranges of cell wall, acid detergent fiber, and cellulose contents (% of DM) in the leaves of shrubs.

Plant	Cell wall					Acid detergent fiber					Cellulose				
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig			
<i>Medicago sativa</i>	38	0.6	**		26 su - 31 f	29	0.1	***	15 sp - 20 su	16	1.5	NS			
<i>Acacia penninsularis</i>	35 f - 45 w	37	0.3	**	20 w - 49 sp	30	0.3	***	12 w - 24 sp	16	0.9	***			
<i>Bursera microphylla</i>	26 w - 51 sp	32	0.3	**	19 f - 22 su	20	0.4	***	3 sp - 19 f	14	1.4	**			
<i>Cercidium floridum</i>	27 f - 29 su	27	0.6	NS	17 w - 27 sp	24	0.5	***	10 w - 17 su	13	0.6	**			
<i>Cyrtocarpa edulis</i>	32 f - 39 su	34	0.3	***	34 w - 35 f	34	0.3	**	12 w - 14 sp	13	1.3	*			
<i>Lippia palmeri</i>	37 su - 50 sp	43	1.3	**	26 su - 30 sp	29	0.5	***	20 w - 24 sp	22	0.5	NS			
<i>Mimosa xantii</i>	32 sp - 40 f	34	0.9	**	16 w - 24 f	20	0.3	***	8 sp - 18 f	12	1.9	NS			
<i>Opuntia cholla</i>	32 f - 52 w	41	0.7	**	28 w - 35 su	32	0.5	***	15 sp - 25 su	18	1.5	*			
<i>Pithecellobium conifine</i>	39 su - 41 f	40	0.6	NS	22 su - 26 f	23	0.2	***	7 sp - 19 su	11	2.4	NS			
<i>Prosopis sp.</i>	33 su - 37 w	34	1.4	NS	28 su - 36 f	31	0.2	***	13 sp - 21 su	17	1.3	NS			
<i>Turnera diffusa</i>	31 su - 46 sp	40	0.9	**											

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; f = fall; w = winter; sp = spring; * (P<0.05); ** (P<0.01); *** (P<0.001); NS = not significant.

Blesilda M.
ippines at Lc

Cutting herb

The rate of hedgerow trees (Stür et al. 1994). Unde necessary in species (Stür trees planted

Materials and methods

The field experiments were carried out in Baños, Ecuador during the study, rainfall and from 33

The soil available P, CEC, The soil design with Erythrina or (Lam.) de Willd. as the main plots. Three

Seeds to form single plant per hill and weeding and

Deeper 12 months before 16 weeks. Cuttings

1 cm) and were cut every 2 hours until a

Results and discussion Tree age at year, total dry weight, percentage increase in dry matter yield

Table 3. Seasonal ranges of hemicellulose, lignin and condensed tannins (% of DM) in the leaves of shrubs.

Plant	Hemicellulose				Lignin				Tannins					
	Range	M	SE	Sig	Range	M	SE	Sig	Range	M	SE	Sig		
<i>Medicago sativa</i>	10	9	0.6	**	7	su	-	15 f	10	0.1	**	4.6 su -	6.8 w	0.0
<i>Acacia penninervis</i>	4 f	-16 w	0.6	**	8 w	-	23 sp	13	0.5	NS	0.0 w -	4.7 f	5.7 0.04 *	
<i>Bursera microphylla</i>	2 sp	-6 w	0.2	**	0.6 w	-	16 sp	6	0.2	*	5.2 sp -	8.3 f	2.9 0.2 NS	
<i>Cercidium floridum</i>	6 su	-8 w	0.4	NS	7.5 w	-	13 sp	10	0.3	*	4.6 su -	7.0 w	6.4 0.07 ***	
<i>Cyrtocarpa edulis</i>	4 f	-14 w	0.4	**	19 sp	-	22 f	21	0.9	**	0.2 f -	0.4 sp	6.2 0.17 ***	
<i>Lippia palmeri</i>	3 su	-14 sp	1.2	**	5 sp	-	9 f	7	0.2	**	4.0 su -	5.4 sp	0.32 0.14 NS	
<i>Mimosa xanthii</i>	0.6 sp	-9 f	4	**	4 w	-	14 su	8	0.3	*	0.0 sp -	0.6 f	0.3 0.28 NS	
<i>Opuntia cholla</i>	5 f	-36 w	20	0.9	10 su	-	16 sp	14	1.8	**	4.7 su -	7.0 w	5.7 0.18 ***	
<i>Pithecellobium constrictum</i>	3 su	-12 w	7	0.7	4 su	-	16 sp	12	0.6	**	0.0 w -	0.9 f	0.5 0.14 ***	
<i>Prosopis sp</i>	8 f	-14 w	10	1.5	NS	-	15 f	12	0.4	**	4.2 su -	7.0 w	5.9 0.16 ***	
<i>Turnera diffusa</i>	3 su	-15 sp	8	0.8	**	-	-	-	-	-	-	-	-	

DM = dry matter; M = mean; SE = standard error; Sig = significance; su = summer; f = fall; w = winter; sp = spring; **(P<0.05); ***(P<0.01); ****(P<0.001); NS = not significant.

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