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IDENTIFICATION AND CHEMICAL COMPOSITION OF FORAGE RESOURCES CONSUMED BY GOATS IN THE MIXTECA REGION OF OAXACA, MEXICO

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ABSTRACT

The Mixteca region of Oaxaca, Mexico, is characterized by extensive grazing of various grasses, shrubs, and trees to raise goats. The objective of this study was to identify and determine the dry matter (DM), organic matter (OM), crude protein, neutral detergent fiber (NDF), and in vitro dry matter digestibility (IVDMD) of the species consumed by goats in the Mixteca region of Oaxaca. The direct observation method was used to collect forage from the species during the rainy (August-September) and dry (April-May) seasons. A botanical collection was made for later identification. The variables considered were the season (rainy, dry) and growth habit (tree, shrub, herbaceous, pod) as treatments. The chemical composition values were analyzed with a completely randomized experimental design. A total of 116 species were identified, of which 74 % were found in the rainy season and 26 % in the dry season. By growth habit, 42 % were trees, 34 % shrubs, and 24 % herbaceous. In addition, 11 % of the total species provided pods that goats consumed. The Fabaceae family was the most represented. Regarding chemical composition, the NDF content of the species was higher ($p \leq 0.05$) in the rainy season. By growth habit, the highest values obtained ($p \leq 0.05$) for DM were in herbaceous and pods; for OM, in pods; for NDF, in pods and trees; and for IVDMD, in trees, shrubs, and pods. The goat livestock of the Mixteca region in Oaxaca has an important ecological niche. The evaluated species maintain a variable chemical composition between the rainy and dry seasons.

Keywords: grazing, goats, tree, shrub, herbaceous, chemical composition.

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INTRODUCTION

Goat farming has a strong presence in the Mixteca region. Their feeding is mainly based on grazing and browsing on trees, shrubs, and herbaceous plants that are found in large areas of land considered as areas of abundant biodiversity (García-

Mendoza *et al*., 2004). These are small-scale systems, with family labor and minimal health practices (Arias *et al*., 2014). The main product of goat farming in the area is the adult animal, so their body condition is the factor that determines the sale price (Ortiz-Morales *et al*., 2021).

One of the problems identified in regional diagnostics of goat production is their limited productivity. This is because the biomass production of the consumed plants varies throughout the year, so there is variety and availability for goats in wet seasons. In contrast, the opposite happens in the dry season, causing a cycle of weight loss-gain. Studies on the use of natural resources for goat production in the Oaxacan Mixteca region are isolated (Arias *et al*., 2014; Franco-Guerra *et al*., 2014). It is reported that the crude protein (CP) content of trees and shrubs generally doubles that of grasses. In addition, neutral detergent fiber (NDF) values between 20 and 35 % have high values of in vitro dry matter digestibility (IVDMD) (Delgado and Ramírez, 2008).

Therefore, it was hypothesized that the nutritional quality of the plant species consumed by goats during grazing varies according to the season, growth habit, and community. This study aimed to identify and determine the chemical composition of plants consumed by grazing livestock during the dry and rainy seasons in the Mixteca region of Oaxaca.

MATERIALS AND METHODS

Area of Study

The study was carried out in five localities (Chocani, CHO; Guadalupe Cuautepec, GC; Guadalupe La Huertilla, GlH; San Marcos Arteaga, SMA; and Santa María Tindú, SMT) of the Mixteca region of the state of Oaxaca (17° 48′ 00″ N, 97° 46′ 00″ W), located in the physiographic province of the Sierra Madre del Sur which has foothills with altitudes between 1000 and 2700 m. The climates are semi-warm subhumid (A)C(w2), (A)C(w1), (A)C(w0) and temperate subhumid C(w2), C(w1), C(w0) (García, 2004). The temperature ranges from 16 to 26 °C, while precipitation fluctuates from 628 to 742 mm. Figure 1 was elaborated from the climatological normal consulted in the National Meteorological Service during the period 1951-2010 for the municipalities of Huajuapan de León, Mariscala de Juárez, Tamazulápam del progreso, and Tezoatlán de Segura y Luna (SMN, 2022).

The representative vegetation types are thorny shrubland, low deciduous jungle, and oak forest.

Sampling

In each community, participatory workshops were conducted with goat producers interested in the study. The workshops were held during the rainy (August-September) and dry (April-May) seasons to learn about the grazing routes that producers typically take with their herds. Two different routes were followed in each community: transhumant and non-transhumant (Ortiz-Morales *et al*., 2021), which were traversed for 6 days. Each grazing day lasted 8 hours per day. Leaves and stems were the plants’

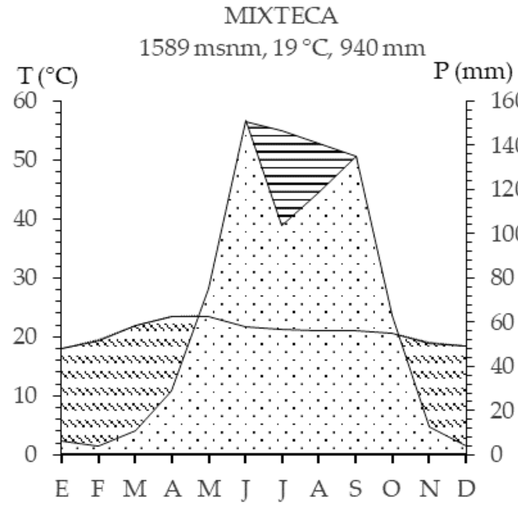

Figure 1. Ombrothermic diagram of the Mixteca region. The average altitude, temperature, and precipitation are shown at the top. The highest temperatures are recorded from March to May, which is considered the driest period. There are intense rains in June and September, with an intra-festival drought recorded in July.

sampled parts considered forage consumed by the goats. 500 g of forage or tree, shrub, and herbaceous pods were collected; the samples were processed for subsequent laboratory analysis. Direct observation method (Arias *et al*., 2014; Mandujano *et al*., 2019) was used for forage sampling. An animal was randomly observed for a minute to determine the species being consumed during grazing; the producers provided the names of each species. In addition, specimens of each plant were collected in triplicate for subsequent botanical identification. A total of 182 samples (35 in CHO, 45 in SMT, 30 in GH, 30 in GC, and 42 in SMA) were collected during both periods.

Chemical composition and degradability

Dry matter (DM), organic matter (OM), and CP were determined as established by the Association of Official Agricultural Chemists (AOAC, 2000), while NDF was evaluated as referred by Van Soest and Wine (1967). IVDMD was determined using the method described by Tilley and Terry (1963).

Statistical Analysis

Considering the period (rainy season, dry season), growth habit (tree, shrub, herbaceous, pod), and communities (CHO, GC, GlH, SMA, SMT) as treatments (Cabrera-Núnez, *et al*., 2019), the concentration of DM, OM, CP, NDF, and IVDMD was compared using a completely randomized experimental design using the GLM procedure, in addition to a Tukey test ($p \leq 0.05$) for the comparison of means using the statistical package SAS (2002). The model used was:

$$Y_{ijk} = \mu + P_k + G_j + C_i + CG_{ij} + CP_{ik} + GP_{jk} + e_{ijk}$$

where Y_{ijk} is the dependent variable; μ, the effect of the overall mean; P_k, the effect of the period; G_j, the effect of growth habit; C_i, the effect of the community; CG_{ij}, the effect of the interaction between community and growth habit; CP_{ik}, the effect of the interaction between community and period; GP_{jk}, the effect of the interaction between growth habit and period; and e_{ijk}, the effect of experimental error.

RESULTS AND DISCUSSION

Species identification

A total of 116 plant species were botanically identified, 86 in the rainy season and 30 in the dry season; furthermore, 18 were present in both periods (Table 1). Of the total, 57 % belonged to the families Fabaceae, Asteraceae, and Fagaceae. Regarding growth habit, 42 % were trees, 34 % were shrubs, and 24 % were herbaceous. Additionally, six trees and seven shrubs produced pods at different times (nine in the rainy season and four in the dry season).

Table 1. Mean values of dry matter, organic matter, crude protein, neutral detergent fiber, and in vitro dry matter digestibility by species, family, period, and growth habit.

Specie	Family	Period	Community	GH	DM	OM	CP	NDF	IVDMD
Quercus sp.	Fagaceae	Rainy	CHO, SMT, SMA	Tr	46.4	91.4	8.9	53.3	79.5
Eysenhardtia polystachya	Fabaceae	Rainy	CHO, SMT, SMA, GC	Tr	49.3	88.7	15.2	50.4	69.5
Heliocarpus americanus	Tiliaceae	Rainy	GlH, SMT, SMA	Tr	62.8	86.1	11.0	44.9	62.3
Bursera aspleniifolia Brandegee	Bureraceae	Rainy	GlH, GC	Tr	47.9	83.2	11.2	46.0	70.8
Leucaena leucocephala	Fabaceae	Rainy	GlH, SMA	Tr	58.0	88.8	11.7	39.1	62.6
Prosopis laevigata	Fabaceae	Rainy	CHO, GlH	Tr	50.8	88.5	21.0	42.3	73.8
Lysiloma acapulcense	Fabaceae	Rainy	SMT, GC	Tr	54.2	90.9	12.5	55.3	75.7
Lysiloma divaricatum	Fabaceae	Rainy	GlH, SMA	Tr	52.8	92.9	14.6	38.8	68.7
Bursera glabrifolia	Bureraceae	Rainy	SMT, GC	Tr	54.9	80.6	10.9	42.4	70.1
Bursera áptera	Bureraceae	Rainy	SMT, SMA	Tr	47.3	87.8	10.3	43.2	73.2
Fraxinus purpusii	Oleaceae	Rainy	SMT, SMA	Tr	46.6	91.1	8.0	36.9	73.3
Acacia bilimekii	Fabaceae	Rainy	SMT, GC	Tr	38.5	89.5	11.7	49.7	68.6
Quercus acutifolia	Fagaceae	Rainy	GC	Tr	46.8	92.1	9.9	55.5	73.4
Cercocarpus macrophyllus	Rosaceae	Rainy	GC	Tr	49.2	87.4	8.3	42.6	65.5
Quercus sebifera	Fagaceae	Rainy	CHO	Tr	40.4	90.8	7.3	51.9	88.8
Cupressus sp.	Cupressaceae	Rainy	SMT	Tr	56.3	92.6	8.1	50.1	85.3
Pinus sp.	Pinaceae	Rainy	SMT	Tr	52.9	93.5	5.2	65.6	84.9
Actinocheita potentillifolia	Anacardiaceae	Rainy	SMT	Tr	52.4	85.6	10.1	39.9	70.2
Quercus magnoliifolia	Fagaceae	Rainy	SMT	Tr	49.1	92.6	8.3	47.0	80.8
Acacia coulteri	Fabaceae	Rainy	GlH	Tr	50.0	88.0	16.2	34.8	70.6
Saurauia aspera	Actinidiaceae	Rainy	CHO	Tr	47.8	88.9	7.8	19.9	84.1
Gliricidia sepium	Fabaceae	Rainy	SMA	Tr	52.4	86.0	16.0	44.5	57.6
Lysiloma tergeminum	Fabaceae	Rainy	GlH	Tr	50.3	90.7	11.8	47.2	69.7
Bunchosia lindeniana	Malpighiaceae	Rainy	SMA	Tr	45.2	88.7	5.4	45.0	67.4

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Table 1. Continue

Specie	Family	Period	Community	GH	DM	OM	CP	NDF	IVDMD
Casimiroa sp.	Rutaceae	Rainy	SMT	Tr	55.6	85.2	13.4	39.5	63.4
Acacia pennatula	Fabaceae	Rainy	SMT	Tr	51.3	92.6	12.4	58.9	88.2
Quercus glaucoides	Fagaceae	Rainy	GC	Tr	49.8	90.2	10.8	53.7	65.2
Bursera fagaroides	Bureraceae	Rainy	SMA	Tr	53.5	86.0	9.1	16.4	53.7
Quercus rugosa	Fagaceae	Rainy	SMT	Tr	42.0	93.6	6.3	66.8	83.3
Leucaena macrophylla	Fabaceae	Rainy	SMT	Tr	62.6	91.1	19.0	61.5	81.9
Cercocarpus betuloides	Rosaceae	Rainy	CHO	Tr	49.2	89.8	9.9	40.5	78.0
Leucaena sp.	Fabaceae	Rainy	CHO	Tr	51.5	90.3	9.4	41.9	84.0
Thevetia thevetioides	Apocynaceae	Rainy	GlH	Tr	66.8	84.3	10.4	42.9	60.3
Bursera linanoe	Bureraceae	Rainy	GlH	Tr	54.9	81.5	9.1	49.6	62.1
Haematoxylon brasiletto	Fabaceae	Rainy	GlH	Tr	46.1	85.2	11.1	33.1	66.4
Acacia cochliacantha	Fabaceae	Rainy	SMT, SMA, GlH, GC	Sh	46.9	90.2	13.6	46.1	76.8
Dodonaea viscosa	Sapindaceae	Rainy	SMT, GC, SMA	Sh	60.1	88.6	10.0	36.2	67.4
Rhus standleyi	Anacardiaceae	Rainy	SMT, CHO	Sh	43.3	92.3	5.8	40.7	80.2
Mimosa fasciculata	Fabaceae	Rainy	GC, SMA	Sh	49.4	91.8	11.6	52.5	70.5
Karwinskia humboldtiana	Rhamnaceae	Rainy	SMA	Sh	55.2	86.4	8.8	49.0	66.3
Amelanchier denticulata	Rosaceae	Rainy	CHO, GC	Sh	38.0	89.1	6.1	39.8	72.4
Mimosa polyantha	Fabaceae	Rainy	GlH	Sh	48.3	82.4	14.1	27.7	56.2
Acacia farnesiana	Fabaceae	Rainy	SMA	Sh	46.8	88.9	22.9	46.5	62.0
Acacia angustissima	Fabaceae	Rainy	SMT, CHO	Sh	47.6	84.6	14.6	29.7	87.2
Zanthoxylum liebmanniana	Rutaceae	Rainy	SMT, SMA	Sh	52.8	86.1	11.4	27.2	47.5
Acacia schaffneri	Fabaceae	Rainy	CHO	Sh	37.4	90.6	17.0	47.7	86.4
Cercocarpus sp.	Rutaceae	Rainy	SMT	Sh	52.5	93.3	9.4	46.6	80.2
Desmodium orbiculare	Fabaceae	Rainy	CHO	Sh	52.4	86.5	13.8	37.3	80.8
Pithecellobium acatlense	Fabaceae	Rainy	GlH	Sh	46.4	89.5	14.5	49.6	81.0
Bourreria obovata	Boraginaceae	Rainy	GlH	Sh	42.9	77.7	7.3	38.1	67.5
Cassia pringlei	Caesalpiniaceae	Rainy	GlH	Sh	57.5	79.0	11.4	32.7	65.0
Brongniartia benthamiana	Fabaceae	Rainy	GC	Sh	62.0	84.4	10.4	36.8	54.4
Pisonia macranthocarpa	Nyctaginaceae	Rainy	GlH	Sh	60.1	81.1	16.7	55.1	75.7
Gagnebina sp.	Fabaceae	Rainy	GlH	Sh	52.1	84.1	12.9	34.8	62.9
Rhus oaxacana	Anacardiaceae	Rainy	SMT	Sh	53.3	93.9	7.4	46.7	74.9
Garrya ovata	Garryaceae	Rainy	CHO	Sh	41.9	89.2	5.6	48.4	79.6
Tecoma stans	Bignoniaceae	Rainy	GC	Sh	38.6	88.6	6.5	40.0	51.5
Caesalpinia melanadenia	Fabaceae	Rainy	SMA	Sh	48.4	88.4	14.2	48.2	81.3
Lindleya mespiloides	Rosaceae	Rainy	CHO	Sh	48.2	88.6	7.3	31.7	75.3
Forestiera phillyreoides	Oleaceae	Rainy	SMA	Sh	50.9	89.6	6.9	37.8	74.9
Forestiera rotundifolia	Oleaceae	Rainy	SMT	Sh	72.2	81.4	12.8	52.2	62.7
Dalea greggii	Fabaceae	Rainy	GC, CHO	He	55.8	89.6	10.6	48.6	77.7
Cosmos sulphureus	Asteraceae	Rainy	SMT, SMA	He	69.6	88.6	11.2	46.6	64.5
Montanoa sp.	Asteraceae	Rainy	SMT, SMA	He	60.1	81.8	10.7	41.5	65.3
Rhynchelytrum repens	Poaceae	Rainy	GC, SMA	He	64.8	88.5	3.8	74.8	57.4
Macroptilium gibbosifolium	Fabaceae	Rainy	SMA	He	61.1	92.7	10.9	58.9	60.3
Montanoa tomentosa	Asteraceae	Rainy	CHO	He	65.9	82.2	19.6	35.5	74.7
Montanoa leucantha	Asteraceae	Rainy	GC	He	47.4	80.4	19.7	30.5	51.9
Calea zacatechichi	Asteraceae	Rainy	SMT	He	63.1	84.7	11.8	31.9	68.8
Tagetes erecta	Asteraceae	Rainy	SMA	He	62.8	89.3	10.8	44.9	54.8
Dalea foliolosa	Fabaceae	Rainy	SMT	He	60.5	86.2	9.4	49.9	77.0
Bidens anthemoides	Asteraceae	Rainy	SMA	He	63.5	74.2	18.4	25.5	60.4
Porophyllum ruderale	Asteraceae	Rainy	CHO	He	69.9	76.0	11.3	22.3	68.7

Table 1. Continue

Specie	Family	Period	Community	GH	DM	OM	CP	NDF	IVDMD
Chamaecrista nictitans	Fabaceae	Rainy	SMA	He	59.9	93.5	13.4	49.8	70.7
Calea ternifolia	Asteraceae	Rainy	GC	He	63.3	83.7	11.3	35.7	58.8
Cissus sp.	Vitaceae	Rainy	GlH	He	66.9	87.3	14.0	41.3	60.5
Salvia lasiantha	Lamiaceae	Rainy	CHO	He	68.0	79.9	20.5	27.5	67.3
Rhynchosia minima	Fabaceae	Rainy	SMT	He	66.7	85.4	13.7	29.8	67.1
Dalea mutabilis	Fabaceae	Rainy	GC	He	53.7	88.3	14.6	45.5	29.6
Salvia sessei	Lamiaceae	Rainy	SMT	He	62.0	88.9	9.7	34.7	83.4
Desmodium angustifolium	Fabaceae	Rainy	SMT	He	69.4	89.0	12.3	55.0	68.9
Tithonia sp.	Asteraceae	Rainy	SMT	He	76.6	79.2	12.6	33.0	69.7
Gonolobus sp.	Apocynaceae	Rainy	GlH	He	68.6	75.1	17.7	27.3	51.0
Bidens pilosa	Asteraceae	Rainy	SMA	He	59.7	86.3	11.3	35.8	68.4
Mimosa albida	Fabaceae	Rainy	SMA	He	61.3	90.5	13.5	51.8	68.7
Montanoa hibiscifolia	Asteraceae	Rainy	SMA	He	48.9	82.2	15.0	32.5	60.3
Quercus sp.	Fagaceae	Dry	SMT, SMA	Tr	54.6	91.0	10.3	44.5	75.9
Cupressus sp.	Cupressaceae	Dry	SMT, GC	Tr	44.8	89.9	6.3	42.0	75.7
Lysiloma acapulcense	Fabaceae	Dry	SMT, GC	Tr	52.2	89.2	10.6	45.5	78.8
Quercus magnoliifolia	Fagaceae	Dry	SMT	Tr	54.6	92.5	7.3	40.6	74.5
Pseudosmodingium multifolium	Anacardiaceae	Dry	SMT	Tr	49.1	92.0	10.3	36.4	67.6
Acacia pennatula	Fabaceae	Dry	SMT	Tr	50.8	90.7	13.5	50.0	80.7
Ficus sp.	Moraceae	Dry	GlH	Tr	70.7	84.2	16.4	49.1	61.5
Quercus glaucoides	Fagaceae	Dry	GC	Tr	47.8	91.3	9.7	46.6	80.7
Salix bonplandiana	Salicaceae	Dry	CHO	Tr	58.1	87.6	16.0	33.4	70.4
Cercocarpus macrophyllus	Rosaceae	Dry	GC	Tr	39.8	87.2	8.0	36.6	69.7
Thevetia thevetioides	Apocynaceae	Dry	GlH	Tr	36.6	82.3	4.9	26.7	65.1
Pinus sp.	Pinaceae	Dry	SMT	Tr	51.9	91.5	5.7	58.1	82.1
Acacia bilimekii	Fabaceae	Dry	GC	Tr	38.2	89.1	13.6	46.7	81.2
Mimosa benthamii	Fabaceae	Dry	GlH	Tr	50.8	89.3	23.4	36.6	61.6
Acacia farnesiana	Fabaceae	Dry	CHO, GC, SMT, SMA	Sh	46.5	87.2	22.1	43.4	65.0
Tecoma stans	Bignoniaceae	Dry	CHO, GC	Sh	56.3	87.4	13.4	33.6	54.5
Acacia cochliacantha	Fabaceae	Dry	GC, SMA	Sh	53.5	89.6	25.8	45.3	78.2
Pistacia mexicana	Anacardiaceae	Dry	CHO	Sh	51.3	91.1	11.1	30.8	60.4
Acacia schaffneri	Fabaceae	Dry	CHO	Sh	41.4	90.1	17.4	54.1	74.1
Rhus oaxacana	Anacardiaceae	Dry	CHO	Sh	54.3	91.3	7.5	32.9	76.4
Cassia mexicana	Fabaceae	Dry	CHO	Sh	50.0	85.9	13.6	28.4	63.5
Pisonia macranthocarpa	Nyctaginaceae	Dry	GlH	Sh	66.0	82.9	23.4	51.6	50.8
Dodonaea viscosa	Sapindaceae	Dry	GC	Sh	45.8	87.3	6.9	23.2	76.1
Rhus chondroloma	Anacardiaceae	Dry	CHO	Sh	50.0	86.7	8.1	33.4	75.2
Baccharis pteronioides	Asteraceae	Dry	CHO	Sh	50.0	90.5	10.0	37.1	78.7
Baccharis salicifolia	Asteraceae	Dry	CHO	Sh	58.1	86.0	17.1	23.4	66.9
Mimosa fasciculata	Fabaceae	Dry	GC	Sh	55.4	88.7	16.2	47.9	75.1
Mimosa calcicola	Fabaceae	Dry	CHO	Sh	48.8	89.9	19.3	42.3	71.7
Dalea filiciformis	Fabaceae	Dry	CHO	He	53.1	88.4	13.9	29.1	67.6
Senecio salignus	Asteraceae	Dry	CHO	He	71.7	83.3	17.7	21.4	59.6
Gymnosperma glutinosum	Asteraceae	Dry	CHO	He	54.1	88.7	9.3	29.7	77.1
Lysiloma divaricatum	Fabaceae	Rainy	SMA, GlH	Pod	66.6	92.0	12.4	45.1	63.1
Acacia cochliacantha	Fabaceae	Rainy	SMA, SMT	Pod	68.0	93.7	6.4	71.3	79.9
Mimosa polyantha	Fabaceae	Rainy	GlH	Pod	61.3	89.2	19.5	51.1	59.5
Acacia angustissima	Fabaceae	Rainy	SMT	Pod	64.0	93.3	17.6	52.8	70.4
Mimosa fasciculata	Fabaceae	Rainy	SMA	Pod	63.5	93.5	9.4	66.2	72.7

Table 1. Continue

Specie	Family	Period	Community	GH	DM	OM	CP	NDF	IVDMD
Acacia pennatula	Fabaceae	Rainy	SMT	Pod	59.5	94.9	6.6	71.5	86.0
Pithecollobium acatlense	Fabaceae	Rainy	GlH	Pod	61.9	93.1	15.0	52.2	72.1
Gliricidia sepium	Fabaceae	Rainy	SMA	Pod	58.6	89.2	17.6	42.8	56.5
Haematoxylon brasiletto	Fabaceae	Rainy	GlH	Pod	60.6	91.5	10.5	46.9	65.2
Acacia farnesiana	Fabaceae	Dry	CHO, SMA	Pod	9.0	89.3	13.2	27.5	53.5
Acacia schaffneri	Fabaceae	Dry	CHO	Pod	61.5	91.2	11.1	22.8	64.4
Prosopis laevigata	Fabaceae	Dry	SMA	Pod	43.9	90.5	10.6	44.3	56.6
Mimosa benthamii	Fabaceae	Dry	GlH	Pod	53.4	90.7	18.0	46.7	59.9

DM: dry matter %; OM: organic matter %; CP: crude protein %; NDF: neutral detergent fiber %; IVDMD: *In vitro* dry matter digestibility %; CHO: Chocani; GC: Guadalupe Cuautepec; GlH: Guadalupe La Huertilla; SMA: San Marcos Arteaga; SMT: Santa María Tindú. GH: growth habit; Tr: tree, Sh: shrub, He: herbaceous.

The Mixteca region is considered one of the regions with the greatest biodiversity due to its heterogeneous vegetation cover. Despite this, there are few studies that systematize information on floristic richness (García-Mendoza *et al*., 2004; Reyes-Santiago, 2012). Knowledge about the structure, composition, and floristic diversity of grazing areas is essential for making decisions about the sustainable management of these natural resources (Lira-Noriega *et al*., 2007). The total number of species identified in the present study is higher than that reported by Arias *et al*. (2014) and Franco-Guerra *et al*. (2014) in the same region. It should be mentioned that these are the only studies that provide information on the use of forest species consumed by goat livestock in the study area. This characterization of species could be considered for the establishment of agroforestry systems or reforestation programs in the region, considering that the territory of the Mixteca has high erosion (Guerrero-Arenas *et al*., 2010). The Fabaceae family is also described in other parts of the country as the most important due to the number of species that goats use (Hernández *et al*., 2008; Salgado-Beltrán *et al*., 2020; García-Fragoso *et al*., 2021). Worldwide, Mexico is the second country with the greatest diversity of plants for this family, where everything from vines and herbaceous plants to shrubs and trees can be found, which are important in the diet of ruminants due to the high protein content in their foliage (Pinto-Ruiz *et al*., 2010) or fruit (Arias *et al*., 2014).

Chemical composition and degradability

PC, NDF, and IVDMD ranged from 23.4–3.8, 74.8–16.4, and 87.2–47.5 %, respectively, by period and growth habit (Table 1). Of all the species, 65 % and 88 % had CP and IVDMD concentrations greater than 10 % and 60 %, respectively, while 96 % maintained values below 60 % of NDF (Table 1). Despite the extensive variety of forage species, their establishment and use have been low and limited to some species (Ayala-Burgos *et al*., 2006; Barrientos-Ramírez *et al*., 2012). In this regard, it is suggested to study and recommend species with forage potential for use in feeding based on their density, biomass productivity (Ramos-Trejo *et al*., 2016), and nutritional value for agro-ecological environments (Jiménez-Ferrer *et al*., 2008; Quero-Carrillo *et al*., 2012) and specific livestock production systems (Arias *et al*., 2014; Franco-Guerra *et al*., 2014).

On the other hand, the percentages of DM, OM, CP, and IVDMD were not different between periods ($p \geq 0.05$) (Table 2). However, during the rainy period, the concentration of NDF was higher ($p \leq 0.05$), which has been previously reported in forages from the humid tropics in Chiapas (Muñoz-González *et al*., 2016). The variation of NDF between periods is due to the fact that during the dry season, the sampled species were in the regrowth stage when the proportion of the secondary wall is lower. Vegetative species in the physiological stage of regrowth or flowering have a higher probability of being consumed by grazing goats because their nutritional value is higher (Mancilla-Leytón *et al*., 2014). Moreover, a high proportion of stems or branches in the samples increases the concentration of NDF because these parts maintain a higher proportion of structural carbohydrates (Cobos *et al*., 2003).

Table 2. Dry matter, organic matter, crude protein, neutral detergent fiber, in vitro dry matter digestibility by period, growth habit, and community.

	N	DM	OM	CP	NDF	IVDMD
Period						
Rainy	136	55.7±9.1	88.1±4.2	11.9±4.8	44.9±11.6 a	68.7±10.8
Dry	46	53.2±14.6	88.7±6.7	13.7±7.7	38.4±18.5 b	67.5±17.1
Growth habit						
Tree	99	50.1±12.1 b	88.9±5.6 b	11.3±6.4	43.1±15.4 ab	72.3±14.3 a
Shrub	40	50.4±13.1 b	87.6±6.1 bc	12.9±6.9	39.1±16.7 b	70.0±15.4 ab
Herbaceous	27	61.5±16.7 a	85.3±7.7 c	13.8±8.9	36.4±21.2 b	64.2±19.6 b
Pod	16	55.9±22.8 ab	91.9±10.5 a	13.2±12.1	48.0±29.1 a	65.9±26.8 ab
Community						
Chocani	35	48.9±19.6 b	88.0±5.9	12.5±7.9 ab	35.9±16.3 b	74.6±16.9 a
Guadalupe Cuautepec	45	50.8±19.3 ab	87.2±5.7	11.9±10.5 ab	44.2±16.4 a	65.9±20.4 b
Guadalupe La Huertilla	30	53.8±17.6 ab	85.9±8.2	14.1±8.8 a	42.4±14.3 a	64.5±12.3 b
San Marcos Arteaga	30	54.7±14.1 a	88.7±6.5	11.9±6.8 ab	45.2±18.5 a	65.4±14.0 b
Santa María Tíndu	42	55.5±13.2 a	88.9±11.8	10.9±5.5 b	47.3±16.4 a	76.3±12.1 a

a,b,c Mean values ± SEM per column with different letter are statistically different ($p \leq 0.05$). DM: dry matter %; OM: organic matter %; CP: crude protein %; NDF: neutral detergent fiber %; IVDMD: *in vitro* dry matter digestibility %.

By growth habit, the percentage of DM was higher ($p \leq 0.05$) in herbaceous and pods, OM in pods, NDF in pods and trees, and IVDMD in trees, shrubs, and pods. The variation in the chemical composition and IVDMD among trees, shrubs, herbaceous, and pods may be caused by the diversity of prevailing factors such as altitude, precipitation, soil type, and available nutrients (Savadogo *et al*., 2007), as they can act as modulators of photosynthesis, altering the nutritional value of the forage (Azcón-Bieto and Talón, 2013).

Goats show adaptation capacity in their grazing behavior by modifying their feeding behavior in response to the variable chemical composition of forage during different seasons of the year, as they can easily switch between the herbaceous, shrubby, or arboreal strata, or vice versa (Ouédraogo-Koné *et al*., 2006; Armenta-Quintana *et al*., 2011; Egea *et al*., 2014). The percentages of DM, CP, NDF, and IVDMD of the species among communities were different ($p \leq 0.05$) (Table 2). The interaction period-growth habit was greater ($p \leq 0.05$) in CP and DM, while the period-community interaction was greater ($p \leq 0.05$) in IVDMD and DM (Table 3).

Table 3. Effect of the interaction between period, growth habit, and community on dry matter concentration, organic matter, crude protein, neutral detergent fiber, and in vitro dry matter digestibility.

Interaction†	DM	OM	CP	NDF	IVDMD
Period – Growth habit	≤ 0.0012	0.4183	≤ 0.0001	0.1108	0.5157
Period – Community	≤ 0.0118	0.9502	0.6399	0.9419	≤ 0.0001
Period – Community – Growth habit	0.6697	0.8175	0.7194	0.7441	0.548

†The variables showed interaction period-community-growth habit ($p \leq 0.05$). DM: dry matter %; OM: organic matter %; CP: crude protein %; NDF: neutral detergent fiber %; IVDMD: in vitro dry matter digestibility %.

CONCLUSION

Goat livestock in the Mixteca region of Oaxaca, Mexico, has an important ecological niche. The number of forage species decreases during drought in grazing areas, and their chemical composition varies between the rainy and drought periods. The collection of pods during the abundance period could be strategic in goat feeding during the drought period due to their high crude protein content.

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