Colegio de Postgraduados

Selection and chemical composition of plant species consumed by goats under drought conditions in three microregions of the Comarca Lagunera, Mexico

Arenas-Báez, Pablo[1]; Maldonado-Jáquez, Jorge A.[2,3]; Garay-Martínez, Jonathan R.[4]; Granados-Rivera, Lorenzo D.[5*]

1 Universidad Autónoma Chapingo, Unidad Regional Universitaria de Zonas Áridas, Bermejillo, Durango, México, C. P. 35230.
2 Colegio de Postgraduados, Campus Montecillo, Montecillo, Estado de México, México, C. P. 56264.
3 Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental La Laguna, Matamoros, Coahuila, México, C. P. 27440.
4 Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental Las Huastecas, Estación Cuauhtémoc, Tamaulipas, México, C. P. 89610.
5 Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Campo Experimental General Terán, Nuevo León, México, C. P. 67400.
* Correspondence: granados.danilo@inifap.gob.mx

ABSTRACT

Objective: To evaluate the plant selection of the diet of goats during the dry season and the chemical composition of the said plants in three microregions of the Comarca Lagunera, Mexico.

Design/Methodology/Approach: Three microregions were identified within the Comarca Lagunera: 1) mountain slope, 2) plain, and 3) cultivation areas. The selection of the goat diet, the availability of forage, and the nutritional composition (CP, EE, DNF, AFD, NFC, TDN, and NEl) of plant species and strata were evaluated in the three microregions.

Results: The shrubs and herbaceous in the Comarca Lagunera had the highest forage availability and a better nutritional profile during winter. On the one hand, these plant strata had an adequate protein content. On the other hand, the overall energy content reached <1 Mcal kg^{-1} DM.

Study Limitations/Implications: The plant strata have an adequate protein content; however, the energy content is not enough and limits growth. Consequently, supplementation programs for grazing dairy goats in the Comarca Lagunera must include sources of energy.

Findings/Conclusions: Regardless of the microregion, the energy content of the species consumed by grazing dairy goats in the Comarca Lagunera is low.

Keywords: Ruminant nutrition, kid production, forage evaluation.

Citation: Arenas-Báez, P., Maldonado-Jáquez, J. A., Garay-Martínez, J. R., & Granados-Rivera, L. D. (2023). Selection and chemical composition of plant species consumed by goats under drought conditions in three microregions of the Comarca Lagunera, Mexico. *Agro Productividad*. https://doi.org/ 10.32854/agrop.v16i12.2764

Academic Editors: Jorge Cadena Iñiguez and Lucero del Mar Ruiz Posadas

Received: August 16, 2023.
Accepted: November 12, 2023.
Published on-line: January 24, 2024.

Agro Productividad, 16(12) suplemento. December. 2023. pp: 25-33.

INTRODUCTION

Mexico and Brazil are the main breeders of goats in the Americas. In these two countries, this economically marginal activity is carried out using native or local goats (Escareño *et al.*, 2012). Nevertheless, the sector has a high social importance, as a result of the income source and the high-quality protein it generates for the low-income population in the rural areas (Ortiz-Morales *et al.*, 2022).

Goat exploitation can be classified according to production (meat or milk) or the feeding system (grazing or confined) (Escareño *et al.*, 2013). In this regard, Alejandre-Ortiz *et al.* (2016) point out that meat production is the most important production system in Latin America and the Caribbean. Large extensions of communal lands are used for this purpose. In Mexico, goat production is carried out in arid and semiarid regions of the country and kids are its main product. These systems are based on native plants grazing (Maldonado-Jáquez *et al.*, 2018). Consequently, increasing the number of births within the herd is the most effective way to improve the production system (Alexandre and Mandonnet, 2005). The number of born, weaning, and survivor kids determines the economic feasibility of a production unit (Casey and Webb, 2010). In this regard, some of the problems that limit productivity in extensive production systems include excessive time to produce the first offspring, low kid productivity, long intervals between births, reduced prolificity, low milk production (as a result of a short lactation period), and a marked reproductive seasonality (Mellado, 2008).

Reproduction is the main factor that limits goat production in Mexico (Andrade-Montemayor *et al.*, 2017). Therefore, reproduction is closely related to goat nutrition, particularly, during gestation. When the nutritional requirements of a goat are not fulfilled, miscarriage becomes a very likely event which has an impact on the number of births (Terrazas *et al.*, 2012). In northern Mexico, the mortality rate can reach up to 50% in winter (dry season) and it can diminish down to 10% in summer (rainy season). This phenomenon is the consequence of a combination of reproductive seasonality, low temperatures and, above all, an inefficient feeding during this period (Mellado *et al.*, 2000).

Consequently, the implementation of supplementation strategies aimed to increase goat milk production is necessary to increase the survival probabilities of the kid. Therefore, information about the nutritional quality of the plant species consumed by goats in the pasture, during the dry season, is required to develop more efficient supplementation strategies (Pinos-Rodríguez *et al.*, 2007; Ramírez-Orduña *et al.*, 2008; Velderrain-Algara *et al.*, 2010). Additionally, producers must consider changes in the availability and the variety of foraging species per microregion (Mellado *et al.*, 2012).

The Comarca Lagunera is a region located between the Mexican states of Durango and Coahuila. This region is the major dairy basin, both for goats and cattle (SIAP, 2011). This region includes sixteen municipalities: five from the state of Coahuila (Francisco I. Madero, Matamoros, San Pedro de las Colonias, Torreón, and Viesca) and eleven from the state of Durango (General Simón Bolívar, Gómez Palacio, Lerdo, Mapimí, Nazas, Rodeo, San Juan de Guadalupe, San Luis del Cordero, San Pedro del Gallo, Tlahualilo, and Cuencamé). It has a mountain slope and a plain and it covers approximately 4,788,750 ha (SEMARNAT, 2010). Consequently, the microregions include plants with different characteristics. The objective of this study was to determine the plant selection of the diet of goats during the dry season and its chemical composition, in three microregions of the Comarca Lagunera, Mexico.

MATERIALS AND METHODS

Study area

The study was carried out in the states of Coahuila and Durango, Mexico, in a region known as the Comarca Lagunera, which is located between 24° 22' N and 102° 22' W, at 1,139 m.a.s.l. According to the Köppen climate classification, this region is classified as BWhw (very dry or desertic climate). The weather is semi-warm, with cold winters. The mean annual precipitation reaches 240 mm. The mean annual temperature is 25 °C in the shade, ranging from −1 °C in winter to 44 °C in summer (García, 2004).

The study began one day after the winter solstice (December 22) of 2021 and was completed on February 22, 2023. A monthly sampling was carried out on December 22, January 22, and February 22. The sampling was conducted in three microregions within the Comarca Lagunera, where goat production activities take place. The first microregion was the mountain slope. This region is characterized by its higher humidity percentage (because of water runoffs) and its higher content of clay in the soil. These factors promote a higher vegetation growth (Villanueva *et al.*, 2011). The second microregion was the plain. It is characterized by its sandy soil with low humidity, as well as its low diversity of plant species (Villanueva *et al.*, 2011). The third region consisted of the cultivation areas. After the harvests, these areas are used by goat producers, as a result of the humidity residues left behind by the irrigation system. This phenomenon increases the abundance and availability of plant species, especially herbaceous (Salinas- González *et al.*, 2015).

Diet selection

Seven multiparous adult goats were selected from each microregion. They were followed during their grazing routes (from 5 to 10 km), with the aim of identifying the plants they selected for their diet. In order to prevent the observers from influencing the behavior of the goats, they were followed by two groups of people, who took notes and collected samples from the species consumed by the goats. Four ≈300-g samples were taken from the plant species consumed by most of the goats (N>75%); the samples were taken at the same height at which the animals fed. The samples included only the leaves of these species. The samples were placed in paper bags for their transportation to the proximal chemical analysis lab. The specimens chosen by the animals were adult plants, with green foliage, which had reached their physiological maturity (Toyes-Vargas *et al.*, 2013).

Forage availability

Forage availability was evaluated in nine permanent plots of 20×20 m (three plots per microregion). The plots were randomly chosen from a map of the study area (100×100 m grid), where the plots located in each of the apexes of the squares could be potentially chosen. Forage availability was determined by species and plant strata (shrubs, cactus, herbaceous, and grass). Shrub availability was estimated following the Adelaide method:

establishing a 20×20 m plot and 3 sub plots of 1×1 m within the first plot (Andrew *et al.*, 1979). Subsequently, a tree and shrub sampling was conducted in the larger plot, counting the branches of each tree or shrub. All the leaves from three or shrubs branches were collected. Additionally, a sampling from the herbs and grasses of the 1×1 m sub plots was carried out, cutting the plants at ground level. Dead grasses or grasses with high lignification were excluded from the process since the goats did not find them appealing.

Lab analysis

In order to determine the dry matter (DM) content, the fresh samples were weighted and, subsequently, dried in a forced air oven at 50 °C, until they reached a constant weight (approximately at 72 h). Additionally, the content (g kg^{-1}) of crude protein (CP), non-fiber carbohydrates (NFC), and ethereal extract (EE) were determined (AOAC, 2019). The neutral detergent fiber (NDF) and acid detergent fiber (ADF) content was likewise established (Van Soest *et al.*, 1991). The values of net energy (Mcal kg^{-1}) for lactation (NEl) were estimated using the Agricultural and Food Research Council model (AFRC, 1993). The total digestive nutrient (TDN) was estimated using the following equation:

$$TDN\,(\%) = \Big(\textit{digestible crude protein} + \textit{digestible non-structural carbohydratres} + \textit{digestible}$$
$$\textit{neutral detergent fiber corrected for protein} + 2.25 \times \textit{digestible ethereal extract}\Big)/100$$

(Pond *et al.*, 2002).

Statistical analysis

An analysis of variance was carried out, considering the plant species as the variation source for the DM, CP, NFC, EE, NDF, ADF, ENl, and TDN variables. Regarding the forage availability variable, the source of variation was the plant strata. The statistical design was completely random, and the means were compare using Tukey's test (α=0.05) in the SAS package (2002). In order to comply with the assumptions of the analysis of variance, the data shown in g/100 g were previously transformed using arcsine.

RESULTS AND DISCUSSIONS

Goats chose to consume the following shrubs: *Larrea tridentata*, *Mimosa monancistra*, *Celtis pallida*, and *Prosopis* spp. Regarding cacti, the goats mainly chose *Opuntia* spp. Meanwhile, goats preferred such herbaceous species as *Amaranthus hybridus*, *Verbena canescens*, *Solanum elaeagnifolium*, and *Tithonia tubaeformis*. Grasses such as *Chloris gayana*, *Bouteloua* spp., and *Cenchrus ciliaris* were the least appealing to goats (Table 1).

These results match the findings of Pinos-Rodríguez *et al.* (2007), Ramírez-Orduña *et al.* (2008), Velderrain-Algara *et al.* (2010), and Mellado *et al.* (2012). These authors evaluated the consumption and diets of goats in northeastern Mexico. The availability of foraging species in the pastures is lower during the droughts than in other seasons; consequently, goats have to adapt to these conditions.

Table 1. Chemical composition of the plant species selected by goats in three microregions of the Comarca Lagunera, Mexico.

Plant	CP	EE	NDF	ADF	NFC	TDN	ENl
	g kg^{-1}						Mcal kg^{-1}
Mountain Slope							
Shrubs							
Larrea tridentata	104.2 c	22.8 a	504.3 c	407.3 b	195.1 a	409.3 b	2.1 a
Mimosa monancistra	121.2 b	24.1 a	531.2 b	296.6 c	163.8 b	477.5 a	1.2 b
Celtis pallida	206.3 a	8.6 b	641.6 a	534.1 a	111.6 c	485.3 a	0.8 c
P-Value	0.001	0.017	0.0013	<.0001	<.0001	0.0285	0.0191
Cacti							
Opuntia spp.	43.2	29.1	302.4	215.8	60.1	524.6	1.8
P-Value	---	---	---	---	---	---	---
Herbacaous							
Verbena canescens	128.1	19.3	567.8	474.1	242	463.5	1.1
Chenopodium album	136.8	20.6	536.7	379.8	236.8	501.7	0.9
P-Value	<.0001	0.011	<.0001	<.0001	0.019	<.0001	0.0014
Grasses							
Cynodon dactylon	79.4	5.3	770.8	470.3	84.7	397.4	0.7
Cenchrus ciliaris	44.3	6.2	806.1	517.3	74.3	416.2	0.8
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0261
Plain							
Shrubs							
Prosopis spp.	212.4	6.3	391.3	276.6	187.4	467.8	1.1
P-Value	---	---	---	---	---	---	---
Herbaceous							
Amaranthus hybridus	179.2	6.4	478.5	364.9	193.7	427.8	1.1
P-Value	---	---	---	---	---	---	---
Grasses							
Chloris virgata	92.6	3.7	665.3	344.8	69.8	413.8	0.5
Bouteloua gracilis	54.1	2.9	722.6	435.4	149.2	410.5	0.6
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivation areas							
Shrubs							
Prosopis spp.	189.3	4.2	401.7	312.6	173.8	453.9	1.0
Larrea tridentata	117.6	17.5	518.4	421.3	188.4	433.2	1.2
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Cacti							
Myrtillocactus geometrizans	63.3	14.6	387.6	271.9	71.2	545.8	1.3
P-Value	---	---	---	---	---	---	---
Herbaceous							
Amaranthus hybridus	236.4 a	7.3 a	467.3 a	378.5 a	187.4 a	453.6 b	1.0 b
Solanum elaeagnifolium	138.9 c	4.7 b	417.8 c	289.6 c	173.6 b	487.3 a	1.0 a
Tithonia tubaeformis	173.3 b	4.1 b	443.6 b	319.8 b	163.2 c	439.5 c	0.9 c
P-Value	<.0001	<.0001	0.0052	<.0001	0.002	0.0403	0.0037
Grasses							
Bouteloua spp.	63.2	1.7	718.3	465.4	136.7	407.9	0.4
Cenchrus ciliaris	47.8	2.6	783.1	567.3	93.8	417.6	0.5
P-Value	<.0001	<.0001	0.0018	<.0001	<.0001	0.0232	<.0001

CP: crude protein, EE: ethereal extract, NDF: neutral detergent fiber, ADF: acid detergent fiber, NFC: non-fiber carbohydrates, TDN: total digestible nutrients, NEl: net energy for lactation. Different letters within the column (a, b, c) indicate significative statistical difference (Tukey; α=0.05).

In this regard, goats have flexible, generalist, and opportunistic feeding strategies, since they consume a great variety of plants in grazing areas. Studies carried out in northeastern Mexico indicate that about 126 plant species make up the diet of grazing goats.

Overall, the forage distribution per plant strata is divided into 40% shrubs, 29% herbs, and 31% grasses (Mellado *et al.*, 2012; Haenlein and Ramírez 2007). However, this study confirms that less than ten plants constitute about 90% of the diet during the whole year (Mellado *et al.*, 2004), particularly during the droughts.

During most of the year, the diet of goats mainly consists of deciduous or perennial shrubs (>50%) (Mellado *et al.*, 2003). The leaves and fresh pods (especially from *Prosopis* spp.) are very nutritious forages (between 189 and 212 g kg^{-1} CP in DM; Table 1). They are staple foods (up to 25% of the diet) during autumn and winter, when the quality and the quantity of the forage are low (Mellado *et al.*, 2004). *Prosopis* spp. is one of the most abundant species in northeastern Mexico; its prevalence has increased in large areas of the Chihuahuan Desert, at the expense of the desert pastures (Fredrickson *et al.*, 2006). Goats consume its leaves with moderation (Mellado *et al.*, 2003). However, the pods of these plants are abundantly consumed by the goats, possibly as a result of their high nutritional content (Abdullah *et al.*, 2011).

Meanwhile, the goats in this study chose *Larrea tridentata*. This perennial xerophytic species was chosen by the goats, regardless of its cover and season of the year. This plant can account for up to 15% of the diet (Mellado *et al.*, 2011). The resistance of *Larrea tridentata* to drought —along with its moderate levels of protein (104-117 g kg^{-1} DM; Table 1) and its continuous metabolic activity under extreme drought conditions (Allen *et al.*, 2008)—seems to be the attribute that makes it appealing to goats.

Meanwhile, herb consumption is lower during winter, as a consequence of its low availability (Mellado *et al.*, 2004). This study confirmed the findings of Mellado *et al.* (2012), who reported that key herbs that the goats from northeastern Mexico prefer are *Amaranthus hybridus*, *Tithonia tubaeformis*, and *Solanum elaeagnifolium*. The goats do not find appealing *Solanum elaeagnifolium* during its flowering stage (Mellado *et al.*, 2008). However, as a result of its high nutrient content (139 g kg^{-1} CP in DM; Table 1), this plant can account for 30% of their diets during winter (Mellado *et al.*, 2014).

In the pastures of northeastern Mexico, goats eat less grasses and the consumption percentage seldom exceed 5% of their diet during any month of the year (Mellado *et al.*, 2004). The results of this study match the findings of Mellado *et al.* (2005), who reported that some of the most consumed grasses are *Bouteloua gracilis* and *Cenchrus ciliaris*. Biomass availability varied according to the plant strata and the microregion (Table 2).

The microregion with the highest biomass production was the mountain slope. In the plains, herbaceous were the plant strata with the highest availability. In the cultivation areas, herbaceous and grasses were the most available plants. There were no significant statistical differences regarding their availability in both microregions. In conclusion, the mountain slope microregion could stand a higher animal load, while the cultivation areas could stand a lower animal load. However, cultivation areas have a higher plant species diversity and the best nutrient profile. Consequently, goat production can reach higher yields in this microregion. Nevertheless, in order to prevent overgrazing, this area must

Table 2. Biomass availability per plant strata with forage potential, in three microregions of the Comarca Lagunera, Mexico.

Plant Strata	Mountain Slope	Plain	Cultivation Areas	P-Value
	t ha^{-1}			
Shrubs	3.67 a	0.30 b	0.02 c	<.0001
Cacti	6.00 a	0.00 c	0.02 b	<.0001
Herbaceous	0.31 b	0.86 a	0.37 b	0.0137
Grasses	0.67 a	0.24 c	0.46 b	0.0406

Different letters within the column (a, b, c) indicate significative statistical difference (Tukey; α=0.05).

have low animal loads. Shrubs and herbaceous are the plant strata with the best nutritional profile. The average CP content in shrubs and herbaceous reached 164 and 170.4 g kg^{-1} DM, respectively. Grasses had the lowest nutrient value (average: 66.3 g kg^{-1} DM) and recorded <1.0 NEl (Table 3).

According to the nutritional composition of the different plant strata, crude protein (CP) in shrubs and herbs is enough to meet the nutrient requirements of goats (approximately 16%). However, the energy available in the different strata is mostly low

Table 3. Chemical composition of plant strata with foraging potential, in three microregions of the Comarca Lagunera, Mexico.

Plant	CP	EE	NDF	ADF	NFC	TDN	ENl
	g kg^{-1}						Mcal kg^{-1}
Shrubs							
Mountain slope	151.7 b	16.9 a	556.8 a	418.3 a	148.7 b	454.3 b	1.3 a
Plain	187.4 a	7.9 c	403.6 c	295.1 c	183.2 a	462.8 a	1.1 b
Cultivation area	152.9 b	11 b	458.1 b	365.8 b	180.7 a	450.2 b	1.1 b
P-Value	<.0001	<.0001	<.0001	<.0001	0.035	0.024	0.0271
Cacti							
Mountain slope	38.7	30.3	317.1	224.7	58.3	514.2	1.7
Plains	---	---	---	---	---	---	---
Cultivation areas	53.2	17.9	368.4	263.5	72.2	534.1	1.3
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Shrubs							
Mountain slope	141.2 b	20.3 a	549.8 a	429.2 a	240.1 a	480.8 a	0.1 b
Plains	182.7 a	5.2 b	476.6 b	371.5 b	201.8 b	418.3 c	1.1 a
Cultivation areas	187.4 a	4.3 b	437.1 c	359.5 c	167.1 c	463.2 b	1.0 a
P-Value	0.041	0.016	<.0001	<.0001	<.0001	<.0001	
Grasses							
Mountain slope	61.3 b	4.2 a	718.4 b	503.2 a	79.3 c	423.5 a	0.6 a
Plains	71.4 a	4.6 a	691.8 c	423.7 b	89.1 b	412.6 a	0.6 a
Cultivation areas	53.6 c	2.3 b	756.3 a	498.1 a	99.5 a	401.2 b	0.57 b
P-Value	<.0001	<.0001	<.0001	<.0001	<.0001	0.018	0.0374

Different letters within the column (a, b, c) indicate significative statistical difference (Tukey; α=0.05).

(<1.0 Mcal kg^{-1} DM). This deficit intensifies, since goats start to lactate during this period; therefore, the consumption of plants with an appropriate energy content is very important (Granados-Rivera *et al.*, 2020). Consequently, the scarce energy content in northeastern Mexico limits the nutritional content of the diets of goats during winter (Maldonado-Jáquez *et al.*, 2017).

CONCLUSIONS

Based on the results obtained in this study, shrubs and herbaceous are the most abundant forage, regardless of the microregion. They also recorded the best nutritional profile during the drought season in the Comarca Lagunera. In addition, these plant strata have an appropriate protein content. However, the low energy content limits the nutritional value of the diet. Therefore, supplementation programs for grazing dairy goats in the Comarca Lagunera must include sources of energy.

REFERENCES

Abdullah, A.Y., Obeidat, B.S., Muwalla, M.M., Matarneh, S.K., & Ishmais, M.A.A. (2011). Growth performance, carcass and meat characteristics of black goat kids fed sesame hulls and *Prosopis juliflora* pods. *Asian-Australasian Journal of Animal Sciences*. 24. 1217–1226. doi: 10.5713/ajas.2011.11061

AFRC. 1993. Energy and Protein Requirements for Ruminants (9th). Wallingford, UK: Agricultural and Food Research Council, CAB International.

Alejandre-Ortiz, M.E., Rubio-Tabárez, E., Pérez-Eguía, E., Zaragoza-Martínez, L., & Rodríguez-Galván, G. (2016). Los recursos caprinos de México. *In*: Vargas-Bayona, J.E., Zaragoza, L., Delgado, J.V., Rodríguez G. (Eds.). Biodiversidad Caprina iberoamericana. Colombia: Ediciones Universidad Cooperativa de Colombia. pp. 94–111.

Alexandre, G., & Mandonnet, N. (2005). Goat meat production in harsh environments. *Small Ruminant Research. 60*(1-2). 53–66. doi: 10.1016/j.smallrumres.2005.06.005

Allen, A.P., Pockman, W.T., Restrepo, C., & Milne, B.T. (2008). Allometry, growth and population regulation of the desert shrub *Larrea tridentata*. *Functional Ecology. 22*(2). 197–204. doi: 10.1111/j.1365-2435.2007.01376.x

Andrade-Montemayor, H.A., Silva, J.C., Escalante, I., & Vera, H.R. (2017). La cabra criolla negra, un recurso zoogenético en peligro: Bases del programa de recuperación en el bajío mexicano. *Revista Mexicana Agroecosistemas. 4*(2-suplemento 3). 29–41.

AOAC. (2019). Official Methods of Analysis of AOAC International (21th). Maryland, USA: Association of Official Analytical Chemists.

Casey, N.H., & Webb, E.C. (2010). Managing goat production for meat quality. *Small Ruminant Research. 89*(2-3). 218–224. doi: 10.1016/j.smallrumres.2009.12.047

Escareño, L., Salinas-González, H., Wurzinger, M., Iñiguez, L., Sölkner, J., & Meza-Herrera, C.A. (2012). Dairy goat production systems: Status quo, perspectives and challenges. *Tropical Animal Health and Production. 45*(1). 17–34. doi: 10.1007/s11250-012-0246-6

Fredrickson, E.L., Estell, R.E., Laliberte, A., & Anderson, D.M. (2006). Mesquite recruitment in the Chihuahuan Desert: Historic and prehistoric patterns with long-term impacts. *Journal of Arid Environments*. 65. 285–295. doi: 10.1016/j.jaridenv.2005.10.019

García, E. (1998). Modificaciones al sistema de clasificación climática de Köppen. 4th. Ed. México D.F.: UNAM.

Granados-Rivera, L.G., Hernández-Mendo, O., & Maldonado-Jáquez, J.A. (2020). Energy balance in lactating goats: Response to mixture of conjugated linoleic acid. *Animal Science Journal. 91*(1). e13347. doi: 10.1111/asj.13347

Haenlein, G.F.W., & Ramírez, R.G. (2007). Potential mineral deficiencies on arid rangelands for small ruminants with special reference to Mexico. *Small Ruminant Research*. 68. 35–41. doi: 10.1016/j.smallrumres.2006.09.018

Maldonado-Jáquez, J.A., Salinas-González, H., Torres-Hernández, G., Becerril-Pérez, C.M., & Díaz-Rivera, P. (2018). Factors influencing milk production in local goats in the Comarca Lagunera, México. *Livestock Research for Rural Development*. 30. 132.

Maldonado-Jáquez, J.A., Granados-Rivera, L.D., Hernández-Mendo, O., Pastor-López, F.J., Isidro-Requejo, L.M., Salinas-Gonzalez, H., & Torres-Hernández, G. (2017). Uso de un alimento integral como complemento a cabras locales en pastoreo: respuesta en producción y composición química de la leche. *Nova Scientia. 18*(9). 55-75. doi: 10.21640/ns.v9i18.728

Mellado, M. 2008. Técnicas para el manejo reproductivo de las cabras en agostadero. *Tropical and Subtropical Agroecosystems*. 9. 47–63.

Mellado, M., Aguilar, C.N., Arevalo, J.R., Rodrıguez, A., Garcıa, J.E., & Mellado, J. (2011). Selection for nutrients by pregnant goats on a microphyll desert scrub. *Animal*. 5. 972–979. doi: 10.1017/S1751731110002715

Mellado, M., Dueñez, J., Foote, R.H., García, J.E., & Rodríguez, A. (2005). Influence of goat densities on vegetation, hydrology and soil properties in a Chihuahuan Desert range. *Annals of Arid Zone*. 44. 111–120.

Mellado, M., Gaytán, L., Rodríguez, A., Macías-Cruz, U., Avendaño-Reyes, L., & García, J.E. (2014). Nutritive content of aborted and non-aborted goat diets on rangeland. *Veterinarija ir Zootechnika*. 67. 68–74.

Mellado, M., Olvera, A., Dueñez, J., & Rodríguez, A. (2004). Effects of continuous or rotational grazing on goat diets in a desert rangeland. *Journal of Applied Animal Research*. 26. 93–100. doi: 10.1080/09712119.2004.9706515

Mellado, M., Rodríguez, A., Lozano, E.A., Dueñez, J., Aguilar, C.N., & Arévalo, J.R. (2012). The food habits of goats on rangelands with different amounts of fourwing saltbush (*Atriplex canescens*) cover. *Journal of Arid Environments*. 84. 91–96. doi: 10.1016/j.jaridenv.2012.03.012

Mellado, M, Salas, G., & Pittroff, W. (2008). *Sphaeralcea angustifolia* as a substitute for alfalfa for growing goats. *Rangeland Ecology and Management*. 61. 405–411. doi: 10.2111/07-082.1

Mellado, M., Valdez, R., Lara, L.M., & López, R. (2003). Stocking rate effects on goats: A research observation. *Journal of Range Management*. 56. 167–173. doi: 10.2307/4003901

Mellado, M., Vera, T., Meza-Herrera, C., & Ruíz, F. (2000). A note on the effect of air temperature during gestation on birth weight and neonatal mortality of kids. *The Journal of Agricultural Science. 135*(1). 91–94. doi: 10.1017/S0021859699007947

Ortiz-Morales, O., Arias-Margarito, L., López-Ojeda, J.C., Soriano-Robles, R., Almaraz-Buendía, I., & Ramírez-Bribiesca, E. (2022). Estudio descriptivo de la producción caprina tradicional en las regiones mixteca y valles centrales de Oaxaca, México. *Ecosistemas y Recursos Agropecuarios. 8*(2). 1-13. doi: https://doi.org/10.19136/era.a8n2.2840

Pinos-Rodríguez, J.M., Aguirre-Rivera, J.R., Mellado, M., García-López, J.C., Álvarez-Fuentes, G., & Méndez-Villazana, J.C. (2007). Chemical and digestibility characteristics of some woody species browsed by goats in Central Mexico. *Journal of Applied Animal Research*. 32. 149–153. doi: 10.1080/09712119.2007.9706866

Pond, W.G., Church, D.C., & Pond, K.R. (2004). Basic animal nutrition and feeding (5th). USA: John Wiley & Sons.

SAS Institute, Inc. (2002). User's Guide of SAS (Statistical Analysis System). SAS Institute Inc.: NC, USA.

Terrazas, A., Hernández, H., Delgadillo, J.A., Flores, J.A., Ramírez-Vera, S., Fierros, A., Rojas, S., & Serafín, N. (2012). Undernutrition during pregnancy in goats and sheep, their repercussion on mother-young relationship and behavioral development of the young. *Tropical and Subtropical Agroecosystems*. 5. S161–S174.

Toyes-Vargas, E., Murillo-Amador, B., Espinoza-Villavicencio, L., Carreón-Palau, L., & Palacios-Espinoza, A. (2013). Composición química y precursores de ácidos vaccénico y ruménico en especies forrajeras en Baja California Sur, México. *Revista Mexicana de Ciencias Pecuarias. 4*(3). 373-386.

Van Soest, P.J., Robertson, J.B., & Lewis, B.A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*. 74. 3583-3597. doi: 10.3168/jds.S0022-0302(91)78551-2