Article

Mesquite pod (*Prosopis* spp.) food for goats in the semi-desert

Martha Gabriela Armijo-Nájera[1]
Alejandro Moreno-Reséndez[2, 4§]
Eduardo Blanco-Contreras[1]
Victoria Jared Borroel-García[3, 4]
José Luis Reyes-Carrillo[2]

[1]Postgraduate in Sciences in Agricultural Production-Agroecology-Autonomous Agrarian University Antonio Narro. Peripherical and highway to Santa Fe, Torreón, Coahuila, Mexico. CP. 27054. (gabrielaarmijo73@gmail.com; blancoce@yahoo.com). [2]Sustainable Systems for Agricultural Production (CASISUPA). (jlreyes54@gmail.com). [3]Polytechnic University of Gómez Palacio. Hightway TheVergel-Torreña km 0 + 820, the Vergel, Gómez Palacio, Durango. CP. 35120. (vborroel@upgop.edu.mx). [4]Academic Network of Innovation in Food and Sustainable Agriculture (RAIAAS)-CIESLAG-COECYT. (vborroel@upgop.edu.mx).

[§]Corresponding author: alejamorsa@yahoo.com.mx.

Abstract

The objective of the present study was to evaluate some chemical, energetic and nutraceutical characteristics of the pod of *Prosopis* spp. in two maturation stages, which was carried out in May and June 2016, in the small property ‘Los Whiles’ located in the municipality of San Pedro de las Colonias, Coahuila, Mexico. The ash content was higher ($p > 0.05$) in mature pods, while the dry matter, acid detergent fiber, neutral detergent fiber, total nitrogen, crude protein and crude fiber was similar ($p > 0.05$) between tender and mature pods. The state of maturity of the pods also did not affect ($p > 0.05$) the energy content, nor the nutraceutical.

Keywords: arid zones, forage, legume, nutraceutical quality.

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Introduction

The *Prosopis* spp. or mesquite is a fast-growing, resistant, perennial shrub that is distributed in semi-arid areas around the world (Chaturvedi and Sahoo, 2013). *Prosopis* has more than 50 species and it is estimated that in Mexico there are about 4 million hectares of mesquite distributed mainly in the arid and semi-arid regions of the country, where *Prosopis leavigata* and *Prosopis glandulosa* represent the most important species (Andrade-Montemayor *et al*., 2011). The ecological importance of this species is that it acts as a nitrogen fixing plant, enriches the soil, promotes the growth of shrubs associated with it, because its root system helps to retain moisture and prevents soil erosion (Villegas-Espinoza *et al*., 2014). In the desert ecosystem, it functions as a shade and refuge for wild and domestic wildlife, since it creates a characteristic microenvironment under its leaf cover that influences the diversity and abundance of mammals, as well as being an effective source of food (Sauceda *et al*., 2014).

Forage quality has been evaluated in non-conventional plant species to compensate for the limited availability of food resources for animals in arid regions (Sawal *et al*., 2004), especially those of the legume family, since they are integrated into often in mixed production systems to improve crop yield through their ability to fix nitrogen (Xu *et al*., 2006) and due to their high protein content could resolve food restrictions in times of critical drought (González *et al*., 2008).

In South America, Africa and India, mesquite pods have been incorporated into feed for cattle, sheep, camels, buffaloes, rabbits and poultry (Sawal *et al*., 2004). Due to its considerable protein levels, the biomass of this tree can contribute to improve the quality of the diet of the animals, satisfy the demand of food in the dry season and stimulate the application of animal production techniques compatible with the environment and natural resources (García and Medina, 2006). Additionally, the utility of the mesquite pod as a supplement in livestock feeding has been highlighted previously (Sawal *et al*., 2004; Mahgoub *et al*., 2005; Andrade-Montemayor *et al*., 2011; Ríos-Saucedo *et al*., 2012) due to its contents of protein (15-21%) and soluble sugars (20%), which increases its palatability (Taweel *et al*., 2005).

On the other hand, the low purchasing power of the inhabitants of these regions makes commercial supplementation for livestock impossible, which is interesting to study in these areas feasible natural resources for the farmer and with adequate nutritional characteristics (Baraza, 2008). In the north of Mexico there are experiences that demonstrate the feasibility of the creation of peasant cooperatives that after the collection and adequate treatment of mesquite pods obtain important benefits as a food supplement for livestock (Febles and Ruiz, 2008).

Finally, because the nutritional content can vary considerably according to the state of maturity of the pod and from one species to another (Sawal *et al*., 2004; Bhatta, *et al*., 2007), it is necessary to evaluate the chemical and nutritional composition. Of the pods of the most promising species of *Prosopis* and of greater geographical distribution in these zones in different stages of maturation, in order to establish the main advantages and limitations in the use of each one for feeding livestock (García and Medina, 2006). Therefore, the objective of the present study was to determine the bromatological characteristics of the fruit of *Prosopis* spp., in two stages of maturation, as an alternative for its potential use in the supplementation of goats of the Comarca Lagunera, Mexico.

Materials and methods

The study was conducted in May and June 2016, on the small property 'Los Whiles' located at coordinates 25° 40' 58" North latitude and 102° 54' 52" West longitude, in the municipality of San Pedro de Las Colonias, Coahuila, in three plots encased with mesquite, each with a different population density.

The region has a territorial extension of 9 942.4 km^2 and a population of 102 650 inhabitants. It is located between parallels 25° 37' and 26° 39' North latitude; meridians 103° 15' and 101° 53' West longitude and altitude between 800 and 2 300. Land use: agriculture (10%) and urban area (0.1%) vegetation: scrub (85.8%), pasture (4%) and forest (0.1%) (INEGI, 2016). In this municipality, the climate corresponds to the semi-warm dry with an average annual temperature of 21.1 °C, an average maximum temperature of 29.9 °C and a minimum average temperature of 12.4 °C. The precipitation is 192.9 mm average per year and the average cumulative annual evapotranspiration is 2 481 mm (Valenzuela-Nuñez *et al*., 2011).

Six samples of *Prosopis* spp., of eight trees previously marked, eight of them in a first sampling and another eight in a later one, were collected. The specimens were placed in perforated paper bags in advance. According to the work of Hardeny Zolfaghari (1988) two samplings were carried out: the first of these was carried out when the pod was in an immature state, 65 days after flowering and the second when the pod was in a mature state, 75 days after flowering. The specimens collected were transferred to the Agroecology Laboratory of the Autonomous Agrarian University Antonio Narro (UAAAN-UL), their initial weight was recorded, they were allowed to dry in a Felisa® forced air oven at 60 ºC until reaching a constant weight, to determine the total dry matter.

Subsequently, in the UAAAN UL Bromatology laboratory, the pods were ground in a Wiley mini mill, model S55PZE-7831 (Thomas Scientific®) with a 1 mm sieve. In each sample, the content of ashes (CC), crude fiber and protein (FC and PC) was determined in duplicate, using the micro-Kjeldahl procedure (AOAC, 1990). While, to determine the fibrous fraction, an analysis of neutral detergent fiber (FDN), acid detergent fiber (FDA) was carried out applying the procedure described by (Van Soest *et al*., 1991).

The content of total digestible nutrients (NDT) and the different types of energy: digestible (ED), metabolizable (EM), net of maintenance (ENm) and net of gain (ENg), as well as the percentage of digestibility of the dry matter (DMS) and organic matter (DMO) were determined using the equations recommended by (Vicente-Perez *et al*., 2015). The equations used are listed below:

NDT= 102.56- (1.4 x FDN)
ED= TND x 0.044
EM= 0.82 x ED
ENm= 1.37 x EM - 0.14EM2 + 0.01EM3 - 1.12
ENg= 1.42 x EM - 0.17EM2 + 0.012EM3 - 1.65
DMS= 88.9 - 0.779 x FDA
DMO= 53.37 + 0.17 x PC

The content of total phenolic compounds was determined according to the Folin-Ciocalteu method (Singleton *et al*., 1999), the total flavonoids were quantified using the methodology described by Lamaison and Carnet (1990) and the antioxidant capacity with the *in vitro* method ABTS according to the methodology developed by Re *et al*. (1999). The three determinations were made in the 16 samples on a dry basis, in triplicate.

All the information was subjected to an analysis of variance under a completely randomized design where the treatment was maturation of the pods (tender or mature), using the GLM procedure of the statistical package SAS (2004). When differences were detected ($p < 0.05$), mean comparisons were made through a Tukey test.

Results and discussion

Pods of *Prosopis* spp. it promises to be an alternative food resource that can be used by the livestock feed processing industries. The usefulness of pods in livestock feeding has been reported previously (Sawal *et al*., 2004; Mahgoub *et al*., 2005; Awawdeh, 2011; Mellado, 2016). The chemical composition (Table 1) of the pods of *Prosopis* spp. in this study it was similar to that reported in mesquite pods by other authors. Ibrahim and Gaili (1985) reported that mesquite pods contained 12.7% crude protein, similar to our values. However, this result was lower than the PC reported in the literature by authors such as Mahgoub *et al*. (2005); Choge *et al*. (2007); Koech *et al*. (2010); Girma *et al*. (2011) whose determined values were 14, 16.2, 18.5 and 15.43%, respectively.

Table 1. Chemical composition of mesquite pods with different level of maturation.

Pods	MS (%)	FDA (%)	FDN (%)	CEN (%)	NT (%)	PC (%)	GRA (%)	FC (%)
Tender	87.838 a	28.501 a	40.589 a	3.7875 b	1.79375 a	11.209 a	0.0635 a	0.14025 a
Mature	85.275 a	30.918 a	43.9 a	4.1125 a	1.92875 a	12.0566 a	0.07 a	0.15475 a

MS= dry matter; FD= acid detergent fiber; FDN= neutral detergent fiber; CEN= ashes; NT= total nitrogen; PC= crude protein; GRA= fat; FC= Raw fiber. Different literals in the columns indicate significant difference (Tukey, 0.05).

According to Abdullah and Hafes (2004) they reported comparable PC and energy contents in pods of *Prosopis* spp. to barley. The higher values reported by previous researchers could be due to different silvopastoral practices that are known to affect the crude protein and dry matter content of the pods (Ribaski, 2012). The CP content of 11.63% in pods was lower than that required for cattle (NRC, 1994). The use of pods as a feed ingredient for livestock is therefore possible only with protein supplementation.

Also, the dry matter content obtained in this study was similar to the value (86.2%) determined by Mahgoub *et al*. (2005), but lower than the values reported in previous studies by Koech *et al*. (2010); Girma *et al*. (2011); Ali *et al*. (2012) with 88.4, 89.7 and 89.15%, respectively. These differences could be due to the stage of harvest, the maturity and the season that determine the MS content in the pods (Oduol *et al*., 1986). Ribaski (2012) reported that silvopastoral practices such as weeding, grazing and wider spacing affect the MS content of *Prosopis* plants.

The contents of FDN and FDA in *Prosopis* pods were higher in this study than the values of 29.8 and 17%, respectively, reported by Ali *et al*. (2012). On the other hand, both FDN and FDA contents were much lower than the values of 51.8 and 29.8%, respectively, reported by Koech *et* *al*. (2010). The pods are rich in carbohydrates, since they comprise 69% dry matter (Choge *et al*., 2007) and can be used as an energy source. The fat content is comparable with the value (0.4%) registered in Peru, but much lower (3.5%) reported in Mexico by Diaz-Celis (1995), respectively. Although this result differs from the results of Girma *et al*. (2011) that recorded 6.1% of the dry matter. While Choge *et al*. (2007) and Odero-waitituch *et al*. (2015) reported a similar content of fat (2.8%), which could explain the low value of gross energy in 15.3 MJ kg^{-1} of dry matter compared to 6.53 MJ kg^{-1} of dry matter in the present study. The variation in fat content can affect the nitrogen-free extract (ELN) of the pods, which is a component that is normally reported in the forthcoming analysis Oduol *et al*. (1986).

The crude fiber content of 14.75% determined is within the range of 16.9-18.99% reported by researchers such as Reddy *et al*. (1990). The value obtained is, however, similar to the 14.6% reported by Girma *et al*. (2011), although lower than that reported by Malik *et al*. (2013), of 5% in pods of *Prosopis cineraria*. The content of raw fiber will limit the level of inclusion in livestock diets, especially in non-ruminants that require a maximum of 5% of total crude fiber based on dry matter. Ruminants are able to tolerate a higher crude fiber content due to the presence of microorganisms in the rumen that ferment the fiber converting it into volatile fatty acids that are absorbed through the wall of the rumen providing energy for animal and ruminal microorganisms (NRC, 1994).

The results of the ash content were higher (p> 0.05) in mature pods, which is similar to the value of 4.5% reported by King`ori *et al*. (2011) and is lower than the values previously reported by Koech *et al*. (2010); Girma *et al*. (2011); Ali *et al*. (2012); Malik *et al*. (2013) who determined contents of 5.2, 6.1, 5.3 and 9.7%, respectively. Additionally, Odero-Waitituch *et al*. (2015) found lower content (2.7%) in mature pods. However, this variation between the data in the literature could be due to the age of the pods at the time of harvest, the type and fertility of the soil, as well as the agro-ecological system under which the trees were grown. According to several authors, the plant species or variety, soil, climate, grazing, vegetable fraction and stage of maturity at the time of sampling affect the nutritional value of forages (Baumont *et al*., 2000; Sawal *et al*., 2004; Bhatta *et al*., 2007; Mellado, 2016).

Prosopis pods are a pleasant food and are a good source of energy for ruminants due to their digestible carbohydrate content. However, the energy content in the *Prosopis* pods in this study was similar (p> 0.05) between tender and mature (Table 2).

Table 2. Energy content of mesquite pods according to the level of maturation.

Component	Pods	
	Tender	Mature
Total digestible nutrients (%)	45.736 a	41.1 a
Digestible energy (Mcal kg^{-1})	2.0124 a	1.8084 a
Metabolizable energy (Mcal kg^{-1})	1.6501 a	1.4829 a
Net energy maintenance (Mcal kg^{-1})	0.799 a	0.6317 a
Net gain power (Mcal kg^{-1})	0.2776 a	0.1154 a
Digestibility of dry matter (%)	66.698 a	64.815 a
Digestibility of organic matter (%)	55.27553 a	55.41963 a

Different literals in the columns indicate significant difference (Tukey, 0.05).

Although the results of the literature attribute this energy value to their carbohydrate content, mainly non-reducing sugars (Del Valle *et al*., 1983; Sawal *et al*., 2004; González *et al*., 2008; Ríos-Saucedo *et al*., 2012). According to Sawal *et al*. (2004) and Baraza *et al*. (2008) mature pods are highly appetizing due to their high energy content (75% and 82.2% of TND, respectively), this is contrary to the results obtained. Similarly, Cuchillo *et al*. (2013) found high values of TND in pods (64.2%) and leaves (65.2%) of *P. laevigata*.

The content of digestible energy was lower than that reported by Cuchillo *et al*. (2013) and Baraza *et al*. (2008) of 2.8 Mcal and 3.6 Mcal, respectively, while the metabolizable energy was similar with the value of 1.53 Mcal, reported by Choge *et al*. (2007), although lower than the values found by authors such as Baraza *et al*. (2008); Obeidat *et al*. (2008); Cuchillo *et al*. (2013) of 2.9 Mcal, 2.6 Mcal and 2.3 Mcal, respectively. In addition, a 4.6% decrease in TND content, 1.88% digestibility of MS and 14% digestibility of MO was observed, which is consistent with the findings of Chaturvedi and Sahoo (2013) who indicated that high content of antinutritional factors in seeds can reduce the availability and digestibility of nutrients in the diet (Chopra and Hooda, 2001; Pasiecznik *et al*., 2001). Previous reports on the composition and nutritional value of *Prosopis* pods agree that they are a potential energy and protein source, although pod composition varies with location (Del Valle *et al*., 1983; González *et al*., 2008; Awawdeh, 2011).

The pods and leaves of *Prosopis* have antinutritional factors such as tannins (Abdulrazak *et al*., 1999) that could hinder digestion and utilization and high sugar content (King`ori *et al*., 2011), which make grinding hygroscopic incorporation in feed is a challenge. Although an in vivo digestibility test was not performed, it is known that the increase of rough forages (eg wheat straw) in the diet favors the ingestion of highly lignified crude fiber, which negatively affects digestibility (Jung and Allen, 1995 Baumont *et al*., 2000).

Conversely, diets rich in grains are rapidly degradable by the microorganisms of the rumen, reflecting a greater splitting of the starch and greater availability of NDT, EM, ENm and ENg (Del Valle *et al*., 1983; González *et al*., 2008; Peña-Avelino *et al*., 2014). The results of the literature indicate that the higher the consumption of EM, the higher the consumption of ENg (Cuchillo *et al*., 2013; Baraza *et al*., 2008). The specific geographical conditions and the age of the plants sampled could play an important role in these discrepancies, as suggested by Baraza *et al*. (2008).

Several reports have pointed out that phenolic compounds contribute to quality and nutritional value in terms of color, taste, aroma and flavor modification and also in the provision of beneficial health effects. Therefore, the content of phenolic compounds, flavonoids and antioxidants of mesquite pods was also estimated (Table 3).

Table 3. Nutraceutical content of pods according to the level of maturation.

Pods	Phenolics (mg equiv AG g^{-1} BS)	Flavonoids (mg equiv Q g^{-1} BS)	Antioxidant (μM equiv Trolox g^{-1} BS)
Tender	0.82433 a	34.838 a	26.00625 a
Mature	0.72524 a	41.061 a	25.96905 a

BS= dry base. Different literals in the columns indicate significant difference (Tukey, 0.05).

Polyphenols are important components in a food ingredient, due to their proven antioxidant capacity. According to Quispe *et al*. (2014) polyphenols are in a range of 1.07 and 2.43 g AG 100 g^{-1}. The total content of phenolic compounds obtained in tender pods, are equivalent (0.82 and 0.89 g AG 100 g^{-1}) to those indicated in the work of Schmeda-Hirschmann *et al*. (2015) in the region of pinte and in the Elqui valley. Likewise, these results are lower than those previously reported by (Andrade-Montemayor *et al*., 2011) in raw pods (5.92 mg AG g^{-1} MS) and roasted pods (4.87 mg AG g^{-1} MS). However, phenolic compounds provide defense mechanisms to plants to neutralize reactive oxygen species (ROS) in order to survive and prevent molecular damage and damage by microorganisms, insects and herbivores (Malik *et al*., 2013).

In relation to the content of flavonoids it was low in tender pods and high in mature, which differs with the results obtained Schmeda-Hirschmann *et al*. (2015) in *Prosopis chilensis* distributed in several regions in Chile. According to Quispe *et al*. (2014) the total flavonoid content is in the range of 24-98. However, the criterion to consider the antioxidant activity of an extract as high, moderate or low is relative. In the present study, high antioxidant activity was observed, which differs with the results of Schmeda-Hirschmann *et al*. (2015) and Quispe *et al*. (2014). The antioxidant activity and the components of the bioactive compounds of grassland vegetation depend to a large extent on the plant species and the part of the plant (Cuchillo *et al*., 2013).

Conclusions

It can be concluded that the mesquite pods, in both stages of maturation (mature and immature), are a good alternative as a complement in the feeding of goats. It is recommended for future work to identify the most prominent mesquite species in the region using the polymerase chain reaction (PCR) technique, since there is very little information about them.

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