Effects of mesquite (*Prosopis laevigata*) pods as a potential feed material for kids

Luz Pena-Avelino[1], Ivonne Ceballos-Olvera[1], Jorge Alva-Perez[1], Jorge Vicente[2], Juan Pinos-Rodriguez[2]*

[1]*Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Tamaulipas, México*
[2]*Facultad de Medicina Veterinaria y Zootecnia, Universidad Veracruzana, México*

*Corresponding author: jpinos@uv.mx

Abstract: To evaluate the dietary inclusion of mesquite pods (*Prosopis laevigata*) on the growth performance, rumen fermentation, nitrogen balance, blood metabolites and carcass traits, 15 Creole goat kids (12.1 ± 2.8 kg body weight) were randomly assigned to one of three experimental diets with 0, 300 and 600 g of mesquite pods (dry matter basis). The study lasted 80 days. At the end of this period, the blood and ruminal fluid were sampled and the nitrogen (N) balance was calculated. The growth performance and feed intake were not affected by the mesquite pods. The nitrogen digestibility, N absorbed, and N retained increased linearly ($P < 0.05$) with the increasing amounts of mesquite pods in the diet. The serum glucose and triglycerides were not affected by the mesquite pods, but the creatinine and uric acid decreased linearly ($P < 0.05$) as the mesquite pods increased in the diet. The highest ($P < 0.05$) rumen pH value, ammonia-N concentration, molar proportion of the acetate and the acetate : propionate ratio was found in the goat kids fed the diet with 600 g when compared to those fed diets with 0 and 300 g mesquite pods. Beneficial dietary effects of mesquite pods on the blood metabolites and N retention of the goat kids were found in this study; therefore, the dietary inclusion of mesquite pods at 600 g/kg can be used as a feed alternative for growing goat kids.

Keywords: *Capra aegagrus hircus*; blood metabolites; feed intake; N excretion; rumen fermentation

In arid regions, feeding conventional grains and commercial concentrates to small ruminants is unsustainable. However, use of unconventional feedstuffs could increase the profitability for smallholder farmers. Mesquite (*Prosopis* spp.) is a tree that is well-adapted to the dry lands of America. It produces sweet, yellow pods with reddish-brown to dark purple tones. A chemical analysis has indicated that mesquite pods contain (per kg dry matter) an average of 856 g of dry matter (DM), 329 g of neutral detergent fibre (NDF), 252 g of acid detergent fibre (ADF), 260 g of sugar, 78 g of crude protein (CP), 41 g of ash, 21 g of fat, and 250 mg of tannins (Pena-Avelino et al. 2014). Feeding trials suggest that mesquite pods at 300 g/kg DM can be used in diets for sheep without affecting the growth performance of sheep and goats (Mahgoub et al. 2005a; Mahgoub et al. 2005b; Obeidat et al. 2008; Kipchirchir et al. 2011).

Cook et al. (2008) determined that short-term mesquite pod consumption does not induce toxicity in goats, but 600 g/kg DM decreased BW (body weight) changes due to the presence of secondary metabolites. Our research group (Negrete et al. 2016; Pena-Avelino et al. 2016) found that 300 g/kg to 500 g/kg DM of mesquite (*Prosopis laevigate*) pods can replace a large proportion of the conventional grains in the diets for finishing lambs and reduce the feeding costs without affecting the health or growth performance. There are no previous

studies that evaluate the effect of 600 g of mesquite pods/kg DM on growing goat kids. We hypothesised that with the correct formulation, mesquite pods can replace conventional grains with no negative effects on the health and performance of the growing goat kids. Therefore, the objective of this study was to evaluate the dietary inclusion of mesquite pods on the growth performance, blood metabolites, rumen fermentation characteristics, N balance and carcass traits of goat kids.

MATERIAL AND METHODS

The experiment protocols, under the supervision and approval (NOM-062-ZOO-1999) of the Academic Animal Welfare Committee of the Universidad Autónoma de Tamaulipas, were conducted in compliance with the Animal Protection Law enacted by Mexico.

Pods, diets and animals

Mesquite pods were obtained from a goat farmer during the summer in Cerritos, San Luis Potosí, Mexico (22°25′48.5″N and 100°18′22″W). The vegetation is mainly xerophytic shrubland dominated by *Yucca filifera* Chab. and *Larrea tridentata* DC Coville. The pods were air dried and passed through a rotating blade forage chopper to reduce the length to 1 cm before mixing into the diets to ensure the proper mixing of the feed ingredients. Fifteen weaned male Creole goats averaging 80 days old and 12.1 ± 2.8 kg body weight (BW) were randomly assigned to one of three experimental diets (5 Creole goats per treatment) in a completely randomised design. The experimental diets contained 0, 300 and 600 g of mesquite pods per kg of diet (dry matter basis), respectively. The nutritional regimes were formulated to replace conventional feedstuffs and maintain similar protein and energy values for growing male goats (NRC 1981). The market price (Table 1) was calculated based on the 2018 prices of the diet ingredients. A total mixed ration diet was offered *ad libitum* to all the goats with free access to fresh water during the study. The residual feed was collected and weighed to record the daily consumption of the dry matter. The feeders always added 10% of the daily surplus food in accord with the intake of each of the animals.

Table 1. The ingredients and chemical composition of the mesquite diet

	Mesquite pods (g/kg DM)		
	0	300	600
Ingredients (g/kg DM)			
Corn maize	630	404	195
Corn stove[1]	207	125	26
Mesquite pods[2]	0	300	600
Soybean meal (440 g/kg CP)	162	170	178
Mineral vitamin premix[3]	1	1	1
Chemical composition			
Dry matter (g/kg)	935	952	939
Crude protein (g/kg)	147	150	151
Ash (g/kg)	69	62	54
Neutral detergent fibre (g/kg)	237	247	263
Acid detergent fibre (g/kg)	158	153	190
Metabolisable energy (MJ/kg)[4]	12.5	12.1	12.1
Market price (US$/ton)	249	220	191

[1]Chemical composition: dry matter: 888 g/kg; crude protein: 48 g/kg DM; neutral detergent fibre: 752 g/kg DM; acid detergent fibre: 390 g/kg DM; ash: 49 g/kg DM; metabolisable energy: 7.5 MJ/kg; [2]Chemical composition: dry matter: 950 g/kg; crude protein: 70 g/kg DM; neutral detergent fibre: 336 g/kg DM; acid detergent fibre: 211 g/kg DM; ash: 44 g/kg DM; metabolisable energy: 12.1 MJ/kg; [3]Composition per kg: Se 10 mg; K 215 mg; Fe 50 mg; Co 20 mg; Zn 50 mg; Mn 1 600 mg; Cu 300 mg; I 70 mg; Ca 220 mg; P 280 mg; S 30 mg; salt 845 mg; urea 102 mg; vitamin A 150 MIU/kg; vitamin D25 MIU/kg; vitamin E 150 IU/kg; lasalocid 1.3 g/kg; [4]ME = metabolisable energy; calculated using NRC (1981)

Growth performance and N balance

The experiment lasted for 80 days preceded by an adaptation period of 12 days. On arrival, the initial BW was recorded. The goats were housed in individual shaded pens (1.0 m × 0.90 m) and fed diets twice a day (08:00 and 15:00 h). The animal weight was measured initially, then every ten days, before the morning feeding throughout the experiment. The total weight gain was calculated by subtracting the initial BW from the final BW. The average daily gain (ADG) was determined by the total BW increase divided by the duration of the trial. The feed conversion ratio (FCR) was calculated as the amount of feed consumed divided by the total weight gain.

The pods and feed samples were dried at 55 °C to a constant weight for the DM determination

and ground in a Wiley mill to pass through a 1 mm screen. The samples were assayed in triplicate for the DM, crude protein (CP) (N × 6.25) and ash content according to the Association of Agricultural Chemists (AOAC 2006). The neutral detergent fibre [NDF; Mertens (2002)] and acid detergent fibre (ADF) were determined by the Van Soest et al. (1991) method and analysed using a fibre analyser (Ankom A200, Ankom Technology, Macedon, NY, USA) with filter bags (Ankom F-57). For the NDF analysis, the samples were treated with α-amylase (Sigma A-3403; Sigma-Aldrich®, St. Louis MO, USA), and the neutral detergent solution contained sodium sulphite. The residues were not corrected for the residual ash. All the diets were formulated with a similar content of protein and energy (150 g of CP/kg DM and 12.1 MJ of ME/kg DM) to meet the requirements of the growing goats (NRC 1981). The NDF and ADF contents were similar among the treatments. The market price in the diet with the level of 600 g of *Prosopis laevigata* pods (PLP)/kg feed lowered the feed costs by 23% (Table 1).

From day 70 to day 75, the N balance was evaluated. The daily faecal output from the goats was collected, recorded and sub-sampled (30 g/day). The faeces were analysed for the DM and N balance. The DM contents of the faecal samples were determined as described above. Urine was collected daily in plastic containers, weighed and recorded. Then, twenty ml of the sub-sample of the acidified urine (6N HCL to ensure a final pH of 3.0 or less) was frozen (–20 °C)**.** The faecal and urine samples were analysed to determine the N balance (AOAC 2006). The difference between the N intake and N output in the faeces and urine was the measure of the N retention.

Blood metabolites

On day 79, before the diurnal feeding, blood samples were collected by jugular vein puncture. The samples were used to determine the concentrations of creatinine, glucose, urea, uric acid and triglycerides. After collection in tubes, the serum was obtained by centrifugation (1 200 × *g* for 20 min) and stored at –20 °C until analysis. The serum chemistry was assayed using a BA-88A Semi-Auto Chemistry Analyzer from Shenzhen Mindray Bio-Medical Electronics Co., Ltd. The serum creatinine concent-

grations were measured using a Spinreact creatinine kit (Creatinine-J; Spinreact, Spain). The absorbance was taken at 492 nm. The glucose was determined using the Glucose Oxidase-Peroxidase (GOD-POD kit) enzymatic endpoint method. The colour intensity was proportional to the glucose concentration in the sample, measured at 500 nm. The serum urea was determined using the Spinreact urea LQ kit (Urea LQ; Spinreact, Spain) at 340 nm. The uric acid was measured using an enzymatic colorimetric test kit from Spinreact SA (Uric acid-LQ uricase-POD™ by Spinreact, Spain) following the manufacturer's instructions. The red dye formed was measured at 520 nm. The cholesterol concentration was measured according to the manufacturer's instructions (GPO-POD, enzymatic colorimetric; Spinreact, Spain). The colour intensity was proportional to the triglyceride concentration in the sample, measured at 500 nm.

Ruminal fermentation indicators

The ruminal fluid samples were collected after slaughter, and the pH was recorded immediately using a pH meter (Hanna Instruments, Inc, Romania). The samples were acidified with 6N HCL, then cooled (4 °C) for 30 min and centrifuged (25 000 × *g*; 4 °C for 20 minutes). The supernatant fluid samples were kept and frozen for further analysis. NH_3-N was determined by the McCullough method (McCullough 1967) using a spectrophotometer of UV-VIS. The volatile fatty acid (VFA) concentration was determined according to Erwin (1961) using a gas chromatograph with a flame ionisation detector (6890N; Agilent Technologies Systems, USA).

Carcass traits

On day 81, goats were sacrificed to evaluate the carcass characteristics. The animals were processed using standard slaughter procedures (NOM-033-SAG/ZOO 2014) described by Colomer-Rocher et al. (1987). After slaughter, the dressed carcass was comprised of the body after removing the skin, the head (at the atlanto-occipital joint), the forefeet (at the carpal-metacarpal joint), and the hind feet (at the tarsal-metatarsal joint). The hot carcasses were weighed and then refrigerated for 24 h at 4 °C for

the cold carcass weight. The reirrigation losses were calculated as the carcass shrinkage loss as described by Zimerman et al. (2008). The dorsal fat was measured using a digital calibrator (Mituyoto, UK) 4 cm from the spinal column at the level of the 12th rib. The full rumen and intestines as well as visceral organs were weighed after slaughter.

Statistical analysis

In all the evaluations, five goats were used per treatment using a completely randomised experimental design. The MIXED model (SAS 2002) was used to analyse the data; the goats were the random component, and the mesquite pod levels were the fixed components. The body weight changes, feed intake, average daily gain and feed conversion were analysed with the same model, except that the time (repeated) and interaction time × mesquite pod level were included in the model. The level of mesquite pods in diets was partitioned into linear and quadratic contrasts. Comparisons of the least square means were conducted using the PDIFF option with a Tukey adjustment. The covariance structure that resulted in the lowest Akaike's information was heterogeneous autoregressive (AR). The differences were considered significant when $P < 0.05$.

RESULTS

The initial average body weight was similar among the treatments, and there were no differences in the final body weight (BW), total gain, average daily gain, dry matter intake and feed conversion. The carcass traits and non-carcass components were not affected by the dietary mesquite pods (Table 2).

The blood serum glucose and triglycerides were not affected by the experimental diets. The serum creatinine and uric acid decreased linearly ($P < 0.05$) as the PLP level increased in the diet. The kids fed the diet with 600 g of mesquite pods had higher blood urea concentrations than the kids fed diets with 0 or 300 g of mesquite pods (Table 3).

The rumen fermentation indicators, except for butyrate, were affected by the experimental diets. The highest ruminal pH values ($P < 0.05$), ammonia-N concentrations ($P < 0.01$), acetate molar proportion ($P < 0.001$) and acetate : propionate ratio ($P < 0.01$) were found in the goat kids fed the diet with 600 g when compared with those found in the kids fed 0 and 300 g of mesquite pods. The total volatile fatty acids concentration ($P < 0.05$) and propionate molar proportion ($P < 0.01$) decreased linearly as the mesquite pod levels decreased in the diet (Table 4).

Table 2. The growth performance and carcass and non-carcass components of the finishing Creole goats fed diets containing the mesquite pods

	Mesquite pods (g/kg DM)			SEM	*P*-value	
	0	300	600		linear	quadratic
Initial body weight (kg)	12.0	11.7	12.6	2.81	0.23	0.35
Final body weight (kg)	22.2	20.9	22.0	5.77	0.70	0.55
Total weight gain (kg)	10.2	9.2	9.4	3.62	0.13	0.83
Average daily gain (kg)	0.127	0.115	0.117	0.045	0.13	0.84
Dry matter intake (kg/d)	0.604	0.608	0.615	0.038	0.18	0.80
Feed conversion	4.7	5.2	5.2	1.03	0.26	0.49
Hot carcass (kg)	10.5	10.0	10.1	2.411	0.64	0.89
Cold carcass (kg)	9.5	9.2	9.6	2.190	0.51	0.83
Hot carcass dressing (%)	48.5	47.8	48.9	2.23	0.75	0.85
Cold carcass dressing (%)	42.8	44.0	43.6	2.09	0.79	0.87
Carcass shrink loss (%)	11.7	7.9	10.8	1.27	0.36	0.54
Dorsal fat at 12th rib (mm)	0.79	0.70	0.75	0.11	0.48	0.79
Full rumen and intestines (kg)	4.7	4.3	4.3	0.97	0.51	0.68
Visceral organs[1] (kg)	7.0	6.6	7.6	0.82	0.71	0.59

[1]blood, skin, head, legs, heart, spleen, lungs, oesophagus, liver, penis and testicles

Table 3. The serum chemistry of the Creole goats fed the PLP diet

	Mesquite pods (g/kg DM)			SEM	P-value	
	0	300	600		linear	quadratic
Creatinine (mmol/l)	0.12[a]	0.10[b]	0.09[b]	0.005	0.002	0.160
Glucose (mmol/l)	6.4	6.3	6.3	0.31	0.716	0.915
Urea (mmol/l)	19.3	15.0	15.3	1.50	0.083	0.235
Uric acid (mmol/l)	0.028[a]	0.016[b]	0.019[ab]	0.003	0.067	0.061
Triglycerides (mmol/l)	0.9	0.8	0.9	0.02	0.972	0.051

[a,b]The means within the rows with the different superscripts are significantly different at $P < 0.05$

Table 4. The rumen fluid pH and volatile fatty acids (VFA) of the Creole goats fed diets with the mesquite pods

	Mesquite pods (g/kg DM)			SEM	P-value	
	0	300	600		linear	quadratic
Rumen pH	6.2[b]	6.3[b]	6.9[a]	0.14	0.051	0.042
Total VFA (mmol/l)	84.2[a]	81.3[a]	72.8[b]	1.12	0.047	0.075
Ammonia-N (mmol/l)	6.4[b]	5.6[b]	7.7[a]	0.93	0.010	0.000 9
Acetate (mol/100 mol)	73.0[b]	74.3[ab]	76.0[a]	1.25	0.002	0.996
Propionate (mol/100 mol)	18.5[a]	18.0[a]	15.8[b]	0.89	0.003	0.453
Butyrate (mol/100 mol)	8.5	7.7	8.2	0.89	0.893	0.600
Acetate : propionate ratio	3.9[b]	4.1[b]	4.7[a]	0.42	0.011	0.329

[a,b]The means within the rows with the different superscripts are significantly different at $P < 0.05$

Table 5. The nitrogen balance in the Creole goats fed diets with the mesquite pods

	Mesquite pods (g/kg DM)			SEM	P-value	
	0	300	600		linear	quadratic
N intake (g/d)	13.9	14.6	15.0	1.14	0.13	0.53
Total N losses[1] (g/d)	6.7	6.6	6.3	0.52	0.18	0.51
Faecal N	3.4	3.4	3.3	0.49	0.49	0.18
Urinary N	3.3	3.2	3.0	0.48	0.35	0.63
N absorbed[2] (g/d)	10.5[b]	11.2[ab]	11.7[a]	0.41	0.004	0.01
N retained[3] (g/d)	7.2[b]	8.0[ab]	8.7[a]	0.59	0.002	0.01
N digestibility[4] (%)	75.5[b]	76.7[ab]	78.0[a]	1.17	0.042	0.01
N retained (% of intake)	51.7[c]	54.8[b]	58.0[a]	1.85	0.002	0.03
N retained (% of absorbed)	68.5[c]	71.4[b]	74.3[a]	1.93	0.003	0.03

[1]Faecal N + Urinary N; [2]N intake − faecal N; [3]N intake − N output; [4](N absorbed × 100)/N intake

[a–c]The means within the rows with the different superscripts are significantly different at $P < 0.05$

The N balance trial indicated that the highest values of N absorbed, N retained, and N digestibility were found in the goats fed diets with 600 g when compared with those fed 0 and 300 g of mesquite pods, although the N intake and total N losses were not affected by the mesquite pod levels in the diet (Table 5).

DISCUSSION

Our results indicated that dietary mesquite pods at 600 g/kg of DM did not induce negative effects on the growth performance, feed intake, or carcass traits. Although previous studies indicated the positive effects of dietary mesquite pods on the growth

performance of goats and sheep, most of them considered the dietary replacement of the forages by mesquite pods (Ravikala et al. 1995; Mahgoub 2005b; Obeidat et al. 2008; Felker et al. 2013). As indicated by Pena-Avelino et al. (2014), mesquite pods had a fat content and fatty acid profile, sugar profile, crude protein content, and degradation rate similar to conventional grains such as maize, wheat and sorghum. Mesquite fruits contain more fibre than conventional grains, but less roughage and by-products than maize stover, wheat straw, cotton seed or wheat bran. Mesquite fruits have been used to replace forages, by-products, conventional grains and commercial concentrates in experiments that did not consider their unique properties when formulating diets (e.g., Mahgoub et al. 2005b; Andrade-Montemayor et al. 2011). Our study considered the reformulation of the experimental diets, which did not greatly differ in the crude protein and energy content. The same studies reported that the feed intake could be reduced by the addition of mesquite pods due to the phenolic components that suppress the appetite, although diets with mesquite pods are more palatable principally due to the higher glucose, fructose and sucrose contents (Pena-Avelino et al. 2014).

The blood creatinine concentrations found in the Creole goat kids remained within the physiological range of 0.08–0.160 mmol/l (Cook et al. 2008). Wang et al. (2016) observed that the starch type affected the blood profile in goats, where the creatinine decreased as the amylose proportion reduced in the diet. Likewise, Giovannetti et al. (2008) reveals thar *Prosopis* pods contain a low amount of starch compared with maize grains. The serum glucose concentrations had a normal range of 4.16–8.32 mmol/l (Wolfensohn and Lloyd 2013). Cook et al. (2008) obtained values of 3.42–3.59 mmol/l in goats fed diets with mesquite pods. The blood triglycerides were within the standard (0.6–1.6 mmol/l) for the goats (Khan et al. 2016). The blood urea-N was higher than the reference value [7.65 to 15.30 mmol/l; Kaneko et al. (2008); Jan et al. (2015)] in all the diet treatments. The fact that mesquite pods increased the blood urea-N concentrations in goats could be associated with the observed increase in the ruminal ammonia. The blood uric acid values were within the reference range (0.020–0.080 mmol/l). The mesquite pods reduced blood uric acid in the goats. The mixed feed with the different ingredients provides a greater diversity

of amino acids (AA), which could promote the NH_3 assimilation. The primary AA that form ammonia in the rumen are Ala, Glu, and Gln (Hackmann and Firkins 2015). Russell (1993) observed that *S. bovis* had a rapid growth rate of 0.9/h on the starch or sugar, stimulating the NH_3 production in the rumen. It is known that *Prosopis* has high glucose and fructose concentrations.

The rumen pH value is determined by the total VFA concentration and buffer capacity of the rumen fluid (Li et al. 2014). The increments of the ruminal pH values by mesquite pods could be attributed to the effective fibre stimulating the chewing activity and promoting saliva production with a buffering capacity (Zhao et al. 2011; Pinho et al. 2018). Another explanation could be the differences in the degradation rate between the mesquite pods and the maize, as confirmed by Pena-Avelino et al. (2016). Maize has a higher starch level than mesquite pods, and so replacing maize with mesquite pods induced a lower molar propionate proportion in the rumen. The high ruminal NH_3-N concentration induced by the mesquite pods could be related to the high concentrations of soluble carbohydrates that help to maximise the efficiency of the microbial protein synthesis in the rumen. Most of these mesquite pod effects on the ruminal metabolism could explain the improved N utilisation in the goat kids.

The concentration of NH_3-N in the rumen is an indicator of the rate of the ruminal N degradation, the concentration of the rumen-degraded N above microbial needs, and the amount of the dietary energy available for the ruminal microorganisms (Li et al. 2011). It is now well established that the N retention depends on the intake of N and the amount of fermentable carbohydrates in the diet (Sarwar and Khwan 2003) such as that provided by the mesquite pods.

These results could be explained by the high ADF present in the diets with the mesquite pods that promote the low degradation of the feed in the rumen, or by the tannins present in the mesquite pods that contribute to forming complexes with protein and fibre (Negrete et al. 2016) and can escape digestion (Min et al. 2015).

The results of this study indicate that *Prosopis laevigata* pods promoted indicators such as the nitrogen digestibility, nitrogen retention, BW gain, and carcass characteristics. Since diets with PLP are inexpensive due to the local availability, they can

be used to overcome the limitations of food sources in the dry tropics. More studies are needed to understand the interaction of the metabolites in this leguminous plant with other ingredients and their influence on different goat breeds and ages.

Conflict of interest

The authors declare no conflict of interest.

REFERENCES

Andrade-Montemayor HM, Cordova TAV, Garcia GT, Kawas JR. Alternative foods for small ruminants in semiarid zones, the case of Mezquite (Prosopis laevigata spp.) and Nopal (Opuntia spp.). Small Rumin Res. 2011 Mar;98(1-3): 83-92.

AOAC. Official method of analysis. 18th ed. Washington, DC, USA: Association of Official Analytical Chemists; 2006.

Colomer-Rocher F, Morand-Fehr P, Kirton AH. Standard methods and procedures for goat evaluation, jointing and tissue separation. Lives Prod Sci. 1987 Dec;17(1):149-59.

Cook RW, Scott CB, Hartmann FS. Short-term Mesquite pod consumption by goats does not induce toxicity. Rangeland Ecol Manag. 2008 Jul;61(5):566-70.

Erwin ES, Marco GJ, Emery EM. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. J Dairy Sci. 1961 May;44(9):1768-76.

Felker P, Takeok G, Dao L. Pod mesocarp flour of North and South American species of leguminous tree Prosopis (Mesquite): Composition and food applications. Food Rev Int. 2013 Jan;29(1):49-66.

Giovannetti MA, Lema VS, Bartoli CG, Capparelli A. Starch grain characterization of Prosopis chilensis (Mol.) Stuntz and P. flexuosa DC, and the analysis of their archaeological remains in Andean South America. J Archaeol Sci. 2008 Jun;35(11):2973-85.

Hackmann TJ, Firkins JL. Maximizing efficiency of rumen microbial protein production. Front Microbiol. 2015 May; 6:1-16.

Jan OQ, Kamili N, Ashraf A, Iqbal A, Sharma RK, Rastogi A. Haematobiochemical parameters of goats fed tannin rich Psidium guajava and Carissa spinarum against Haemonchus contortus infection in India. J Parasit Dis. 2015 Marz;39(1):41-8.

Kaneko JJ, Harvey JW, Bruss ML. Clinical biochemistry of domestic animals. 6th ed. San Diego, CA, USA: Elsevier Academic Press; 2008.

Khan KMH, Ali MK, Abdullah MM, Amin SAH. Reference values for haemato-biochemical parameters in the Maraz goats. ROAVS. 2016 Apr;6(2):74-7.

Kipchirchir KO, Kinuthia RN, Wahome RG. Use of dry land tree species (Prosopis juliflora) seed pods as supplement feed for goats in the arid and semi-arid lands of Kenya. Environ Res J. 2011 Feb;5(2):66-73.

Li Q, Gao Y, Cao Y, Feng Z, Li J. Effects of rumen-degradable protein balance on rumen fermentation in continuous culture fermenters. Front Agric China. 2011 Nov;5: 598-604.

Li F, Li Z, Li S, Ferguson JD, Cao Y, Yao J, Sun F, Wang X, Yang T. Effect of dietary physically effective fiber on ruminal fermentation the fatty acid profile of milk in dairy goats. J Dairy Sci. 2014 Apr;97(4):2281-90.

Mahgoub O, Kadim IT, Forsberg, NE, Al-Ajmi DS, Al-Saqry NM, Al-Abri AS, Annamalai K. Evaluation of Meskit (Prosopis juliflora) pods as a feed for goats. Anim Feed Sci Tech. 2005a Jun;121(3):319-27.

Mahgoub O, Kadim IT, Johnson EH, Srikandakumar A, Al-Saqri NM, Al-Abri AS, Ritchie A. The use of a concentrate containing Meskit (Prosopis juliflora) pods and date palm by-products to replace commercial concentrate in diets of Omani sheep. Anim Feed Sci Tech. 2005b May; 120(1-2): 33-41.

McCullough H. The determination of ammonia in whole blood by a direct colorimetric method. Clin Chim Acta. 1967 Aug;17(2):297-304.

Mertens DR. Gravimetric determination of amylase-treated neutral detergent fibre in feeds with refluxing beakers or crucibles: Collaborative study. JAOAC. 2002 Dec;85(6): 1217-40.

Min BR, Solaiman S, Terrill T, Ramsay A, Mueller-Harvey I. The effects of tannins-containing ground pine bark diet upon nutrient digestion, nitrogen balance, and mineral retention in meat goats. J Anim Sci Biotechno. 2015 Jun; 6(1):1-8.

Negrete LO, Pinos-Rodriguez JM, Grajales-Lagunes A, Morales JA, Garcia-Lopez JC, Lee-Rangel HA. Effects of increasing amount of dietary Prosopis laevigata pods on performance, meat quality and fatty acid profile in growing lambs. J Anim Physiol Anim Nutr. 2016 Oct;101(5): 303-11.

NRC. Nutrient requirements of goats: Angora, dairy, and meat goats in temperate and tropical countries. Vol. 15. Washington, DC, USA: National Academies Press; 1981.

Obeidat BS, Abdullah AY, Al-Lataifeh FA. The effect of partial replacement of barley grains by Prosopis juliflora pods on growth performance, nutrient intake, digestibility, and carcass characteristics of Awassi lambs fed finishing diets. Anim Feed Sci Tech. 2008 Sep;146(1-2):42-54.

Pena-Avelino LY, Pinos-Rodriguez JM, Yanez-Estrada L, Juarez-Flores BI, Mejia R, Andrade-Zaldivar H. Chemical composition and in vitro degradation of red and white mesquite (Prosopis laevigata) pods. S Afr J Anim Sci. 2014 Oct;44(3):298-306.

Pena-Avelino LY, Pinos-Rodriguez JM, Juarez-Flores BI, Yanez-Estrada L. Effects of Prosopis laevigata pods on growth performance, ruminal fermentation and blood metabolites in finishing lambs. S Afr J Anim Sci. 2016 Dec;46(4):360-5.

Pinho RMA, Santos EM, de Oliveira JS, de Carvalho GGP, da Silva TC, Macedo AJDS, Correa YR, Zanine AM. Does the level of forage neutral detergent fiber affect the ruminal fermentation, digestibility and feeding behavior of goats fed cactus pear? Anim Sci J. 2018 Oct;89(10): 1424-31.

Ravikala K, Patel AM, Murthy KS, Wadhwani KN. Growth efficiency in feedlot lambs on Prosopis juliflora based diets. Small Rum Res. 1995 May;16(3):227-31.

Russell JB. Effect of amino acids on the heat production and growth efficiency of Streptococcus bovis: Balance of anabolic and catabolic rates. Appl Environl Microb. 1993 Jun;59(6):1747-51.

Sarwar M, Khan MA. Nitrogen retention and chemical composition of urea treated wheat straw ensiled with organic acids or fermentable carbohydrates. Asian-Australas J Anim Sci. 2003 Jan;16(11):1583-92.

SAS. SAS user's guide. Cary, NC, USA: SAS Institute Inc.; 2002.

Van Soest PV, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci. 1991 Oct; 74(10):3583-97.

Wang SP, Wang WJ, Tan ZL. Effects of dietary starch types on rumen fermentation and blood profile in goats. Czech J Anim Sci. 2016 Jan;61(1):32-41.

Wolfensohn S, Lloyd M. Handbook of laboratory animal management and welfare. 4th ed. New York, USA: John Wiley & Sons, Ltd.; 2013.

Zhao XH, Zhang T, Xu M, Yao JH. Effects of physically effective fiber on chewing activity, ruminal fermentation, and digestibility in goats. J Anim Sci. 2011 Feb;89(2):501-9.

Zimerman M, Doming E, Lanari MR. Carcass characteristics of Neuquén Criollo kids in Patagonia region, Argentina. Meat Sci. 2008 Jul;79(3):453-7.