DIAGNOSIS OF THE PALATABILITY OF FRUITS OF THREE FODDER TREES IN RUMINANTS

Diagnóstico de la palatabilidad del fruto de tres árboles forrajeros en rumiantes

Saúl Rojas-Hernández[1], Jaime Olivares-Pérez[1*], Fredy Quiroz-Cardoso[1], Abel Villa-Mancera[2], Moisés Cipriano Salazar[1], Luis Miguel Camacho Díaz[1], Alejandro Reynoso Palomar[2]

[1] Unidad Académica de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Guerrero, km. 3.0 Carretera Ciudad Altamirano-Iguala, Col. Querenditas, CP. 40660, Municipio de Pungarabato Guerrero, México.
[2] Laboratorio de Genética y Reproducción, Facultad de Medicina Veterinaria y Zootecnia, Benemérita Universidad Autónoma de Puebla, Calle 4 Sur No. 304, CP. 75480, Centro. Tecamachalco, Puebla, México.
*Corresponding author: olivaares@hotmail.com

Scientific note **received:** september 9, 2014, **accepted:** may 11, 2015

ABSTRACT. The chemical composition, *in vitro* dry matter (IVDMD) and organic matter (IVOMD) digestibility of the fruits of *Pithecellobium dulce*, *Acacia farnesiana* and *Acacia cochliacantha* were determined. A cafeteria test in calves, sheep and goats was developed to determine through consumption of dry matter and coefficient of preference the palatability of these fruits as a feed source. Crude protein and neutral and acid detergent fiber contents were higher in the *A. cochliacantha* fruit ($p < 0.001$) with 11.1, 55.0 and 38.3 %, respectively. Total phenols were higher ($p < 0.001$) in *A. farnesiana* fruit with 39.7 %. The IVDMD and IVOMD were greater ($p < 0.001$) in *P. dulce* fruit with 57.7 and 35.6 %, respectively. The *P. dulce* fruit was more palatable ($p < 0.0001$) for calves and those of *A. cochliacanta* for sheep and goats ($p < 0.05$). It is concluded that palatability was higher for *A. cochliacanta* and *P. dulce* fruits due to their chemical composition.
Keywords: Palatability, fruits, trees, ruminants

RESUMEN. Se determinó la composición química y digestibilidad *in vitro* de materia seca (DIVMS) y orgánica (DIVMO) de frutos de *Pithecellobium dulce*, *Acacia cochliacantha* y *Acacia farnesiana*. Se realizaron pruebas de cafetería en becerros, ovinos y caprinos, para determinar el consumo de materia seca y coeficiente de preferencia de palatabilidad de frutos como fuente de alimento. El contenido de proteína cruda, fibra detergente neutra y acida fue mayor en el frutos de *A. cochliacantha* ($p < 0.001$) con 11.1, 55.0 y 38.3 %, respectivamente. Los fenoles totales fueron mayores ($p < 0.001$) en frutos de *A. farnesiana* con 39.7 %. La DIVMS y DIVMO fue mayor ($p < 0.001$) en frutos del *P. dulce* con 57.7 y 35.6 %, respectivamente. Los frutos de mayor palatabilidad fueron *P. dulce* ($p < 0.0001$) en Becerros y *A. cochliacanta* en Ovejas y Cabras ($p < 0.05$). La palatabilidad de los frutos de las arbóreas estuvo determinada por la composición química.
Palabras clave:: Palatabilidad, frutos, árboles, rumiantes

INTRODUCTION

Fodder trees have been recognized in many parts of Mexico as a strategic biomass resource for livestock, which can help meet animal feed requirements in critical periods (Olivares *et al.* 2013a), without diminishing nutrient intake (Seresinhe *et al.* 2012). The selecting of feed by animals depends on its palatability, which is a complex phenomenon that is determined by factors inherent to the animal as well as to feed properties. The preference tests developed by Mokoboki *et al.* (2011) have demonstrated the usefulness of conducting cafeteria tests in ruminants for determining differences in palatability of feed obtained from trees. In the Mexican tropics, *Pithecellobium dulce*, *Acacia far-*

nesiana and *Acacia cochliacantha* trees are found scattered in pastures and in living fences where ruminants harvest the fruit to feed themselves in the dry season according to the animal´s ability (Olivares *et al*. 2011). The objective was to determine the chemical composition and digestibility of the fruits of *P. dulce*, *A. cochliacantha* and *A. farnesiana*, as well as the preference that ruminants have for them as an indicator of their palatability, in order to provide additional important information regarding ruminant nutrition.

MATERIALS AND METHODS

The study was performed in the Tierra Caliente region of Guerrero, located at 18° 20' 30" north latitude, and 100° 39' 18" west longitude. The climate is Aw0, the driest of the warm subhumid area with summer rains. The average temperature and rainfall are 28 °C and 1010.7 mm, respectively (Fragoso 1990).

Chemical composition and *in vitro* digestibility of fruits

Three samples of 500 g of ripe fruit from each tree were collected, dried at 40 °C for 72 h to constant weight, ground with a Willey mill with a 1 mm sieve and used for chemical composition analysis. Samples were analyzed for dry matter (DM) by drying at 105 °C for 24 h in a forced air oven (AOAC 2000; ID 954.01). Ash (AOAC 2000) and crude protein (CP) were determined by the Kjeldahl method (AOAC 2000; ID 954.01). Acid detergent fiber (ADF), neutral detergent fiber (NDF) (Van Soest *et al*. 1991), total phenol content (TP) (Folin ciocalteu) and condensed tannins (CT) (butanol-HCL) were determined using the methodology described by Waterman and Mole (1994).

The *in vitro* digestibility of dry and organic matter (IVDMD and IVOMD) was determined by the gas production technique at 96 h incubation as modified by Herrero and Jessop (1996). The IVDMD was calculated as the difference between the dry matter (DM) contained in the initial substrate minus the DM in undegraded substrate). The IVOMD was calculated as the difference between the organic matter (OM) contained in the initial substrate minus the OM in undegraded substrate.

Cafeteria test

The fruits of *P. dulce*, *A. farnesiana* and *A. cochliacantha*, trees native to Mexico and reportedly more abundant in the country´s tropical regions than anywhere else, were used (Olivares *et al*. 2011). The fruits were crushed to two cm particle size for feeding. The animals used were four cross male calves *Bos taurus* / *Bos indicus* with live weight of 170.0 ± 15.0 kg; eight male sheep hybrid Dorper-Pelibuey of 18.5 ± 1.5 kg live weight and eight entire creole male goats of 20.6 ± 1.8 kg live weight, housed in individual pens with free access to food and water bowls. At the beginning of the experiment the animals were dewormed with albendazole sulfoxide (4.5 mg kg^{-1} BW^{-1} oral route) and were given vitamins A, D and E.

Bovines

Four calves housed in individual 2 x 4 m pens were used. The treatments were the fruits of the trees *P. dulce* and *A. cochliacantha*. Four kg DM $animal^{-1}$ d^{-1} of each fruit were offered for two hours a day before going to pasture (7:00 to 9:00 h) in individual feeders with daily rotation, to avoid the conditioning of animals. The study lasted fifteen days, comprising eight days for adaptation and seven for evaluation.

Sheep and Goats

Eight sheep and goats were housed in individual 1 x 1.2 m pens. The treatments were the fruits of the trees *A. cochliacantha* and *A. farnesiana*. 500 g DM $animal^{-1}$ d^{-1} of each fruit in individual troughs were offered daily with rotation to avoid the conditioning of animals. Also, oat hay as basal diet was provided as an additional fodder. The study lasted twenty-five days, 10 d for adaptation plus fifteen for evaluation.

Variables measured

Palatability was determined by the animals' dry matter intake (DMI), subtracting the amount of fruit rejected daily by the amount offered (Alonso *et al*. 2008, Alonso *et al*. 2009, Olivares *et al*. 2013b), and the coefficient of preference (COP) was calculated from the ratio between the intake of individual fruits divided by the average consumption of fruits (Olivares *et al*. 2013b).

Statistical analysis

The data of the variables chemical composition and digestibility of fruit by general linear models (GLM) were analyzed in a completely randomized design; model: $Y_{ij} = \mu + T_i + \xi_{ij}$ where: Y_{ij}= variable response to the treatment (i) in the repetition (j); μ= overall mean; T_i = treatment effect (i); $\xi\ ij$ =random error of treatment (i) in the repetition (j), terms n-1 (σ^2,0) (SAS 2002).

The preference study data variables (DMI and COP) were analyzed in a completely randomized design with a factorial arrangement, using the statistical model: $Y_{ijk} = \mu + T_i + \sigma_{ij} + P_k + (TxP)_{ik} + \varepsilon_{ijk}$; Where, Y_{ijk} is the response to the ith treatment in the jth measurement in the kth period; μ is the overall mean; T_i is the effect of ith treatment (two fruits); σ_{ij} is the error associated with the experimental unit in the ith treatment (four calves and eight sheep and goats; Pk is the period effect (seven days in calves and fifteen days in sheep and goats); (T x P)$_{ik}$ is the interaction treatment*period; and ε_{ijk} is the error associated with periods. Comparison of means between treatments in the two designs was performed with the Tukey test ($p < 0.05$).

RESULTS AND DISCUSSION

Chemical composition

The content of CP, ADF, NDF and CT was higher ($p < 0.001$) in the fruit of *A. cochliacantha* with 14.5, 38.3, 55.0 and 4.6 %, respectively (Table 1). The total phenol content was higher in the fruit of *A. farnesiana* with 39.7 %. The fruit of *P. dulce* was the most digestible ($p < 0.001$) with 57.7 % in dry matter and 35.6 % in organic matter (Table 1).

In general, the protein content in the fruits of the three tree species was between 10.2 and 14.5 % on a dry matter basis, which covers the required minimum of 8.0 % to ensure the efficient functioning of the rumen micro flora (Van Soest 1994). On the other hand, ADF and NDF contents in the fruit of *P. dulce* (Table 1) is below that reported for fruits in other tree species (*Guazuma ulmifolia, Crescentia alata, Acacia nilotica* and *Acacia sieberiana*); however, the detergent fiber content of *A. cochliacantha* fruit is higher (Mlambo *et al*. 2011, Rojas-Hernandez *et al*. 2015). The highest ADF and NDF contents were found in the *A. cochliacantha* fruit, suggesting the presence of high concentrations of cellulose, hemicellulose and lignin, as described by Mlambo *et al*. (2011) and Olivares *et al*. (2013b), which decreased IVDMD and IVOMD in this fruit (Table 1).

Cafeteria test in ruminants

Bovines: The calves showed a higher consumption ($p < 0.0001$) of *P. dulce* fruit from the third to the seventh day of the experiment with 1.57, 1.70, 2.14, 2.14 and 2.20 kg DM animal^{-1} d^{-1}, respectively, compared to dry matter intake (DMI) of the A. cochliacantha fruit (Figure 1). The effect of the feeding period only is observed in DMI of the P. dulce fruit with a significant increase ($p < 0.04$) from the first day with 0.54 kg animal^{-1} d^{-1}, to the third, fourth, fifth, sixth and seventh day with up to 2.20 kg DM animal^{-1} d^{-1} (Figure 1). The COP was higher for the *P. dulce* fruit ($p < 0.0001$) with a range of 1.74 to 1.96 units, compared to that observed for the *A. cochliacantha* fruit (Figure 1).

The calves' preference for the *P. dulce* fruit (Figure 1) was associated with higher *in vitro* dry and organic matter digestibility of this fruit (Table 1). The levels of ADF and NDF affect the digestibility of food and this can have an effect on dry matter intake by the animal (Gregorini *et al*. 2015). The rejection of *A. cochliacantha* fruit by calves could be related to the higher content of total phenols and condensed tannins (Table 1), compounds responsible for the astringency and de-

Tabla 1. Chemical composition and *in vitro* digestibility (%) of three fodder tree fruits on a dry matter basis

	Fruits			SEM p-value
	P. dulce	*A. cochliacantha*	*A. Farnesiana*	
Crude protein	10.2^c	14.5^a	12.8	0.3^{**}
Ash	6.5^a	3.6^b	4.9^{ab}	0.4^*
Neutral detergent fiber	20.9^b	55.0^a	23.0^b	0.5^{**}
Acid detergent fiber	14.7^c	38.3^a	16.2^b	0.8^{**}
Total phenols	3.0^b	5.0^b	39.7^a	0.3^{**}
Condensed tannins	1.8^b	4.6^a	2.4^b	0.5^{**}
In vitro DM digestibility	57.7^a	26.1^b	34.7^{ab}	8.7^{**}
In vitro OM digestibility	35.6^a	15.4^b	33.5^a	6.5^{**}

^{abc} Significance of values in the same line, Tukey ($^*P < 0.01$; $^{**}p < 0.001$). SEM: Standard error of means; DM: dry matter; OM: organic matter

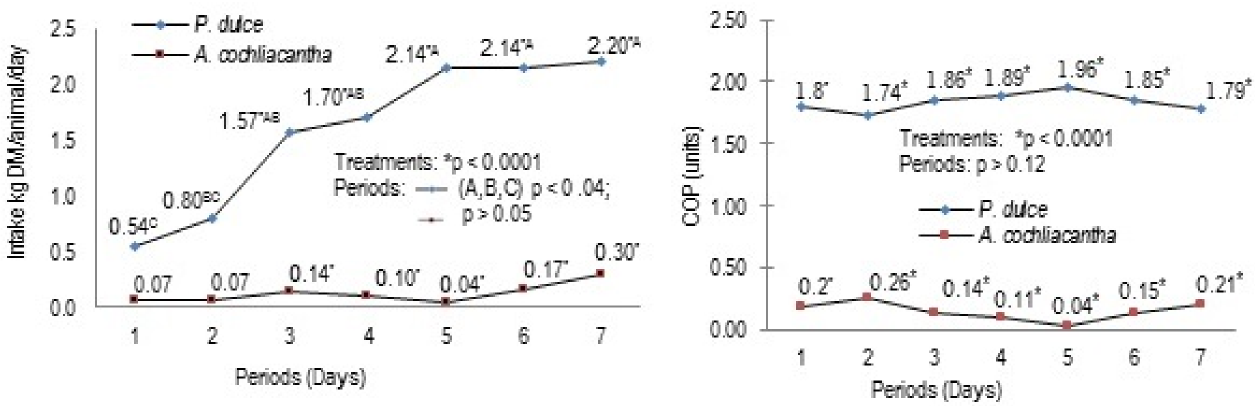

Figura 1. Palatability of two tree fruits by growing calves (COP: coefficient of preference)

creased palatability (Patra and Sexena 2011).

Sheep: Sheep on the fifth day of the experiment consumed more ($p < 0.05$) *A. cochliacantha* fruit with 0.29 kg DM animal^{-1} d^{-1} and this level was maintained until the fifteenth day of the experiment with 0.42 kg DM animal^{-1} d^{-1} (Figure 2). In relation to consumption dynamics during the study period, it was observed that fruit intake by sheep increased significantly ($p < 0.0001$). In *A. cochliacantha* fruit, it increased from the first day with 0.17 kg DM animal^{-1} d^{-1} to 0.44, 0.45 and 0.42 kg DM animal^{-1} d^{-1} on the ninth, tenth and fifteenth day, respectively. In *A. farnesiana* fruit, consumption initiated with 0.15 kg animal^{-1} d^{-1} and peaked on the tenth day of consumption with 0.38 kg DM animal^{-1} d^{-1} and ended with 0.32 kg DM animal^{-1} d^{-1} (Figure 2). The COP of the sheep for *A. cochliacantha* fruit ranged between 1.04 to 1.16 units and was higher ($p < 0.05$, $p < 0.01$, $p < 0.001$) than the COP for *A. farnesiana* fruit (Figure 2). In relation to COP dynamics during the study period, it was observed that fruit intake by sheep by tree species did not differ ($p > 0.05$) (Figure 2). In sheep the higher intake and COP for *A. cochliacantha* fruit (Figure 2) are attributed to its high crude protein and low total phenol content, compared to the levels observed in *A. farnesiana* fruit (Table 1); this behavior was similar to that reported by Alonso *et al.* (2009) and Olivares *et al.* (2013b) in small ruminants.

Goats: In goats there were no differences ($p > 0.05$) in the consumption of fruits of *A. cochliacantha* (0.19 to 0.49 kg DM animal^{-1} d^{-1}) and *A. farnesiana* (0.18 to 0.45 kg DM animal^{-1}

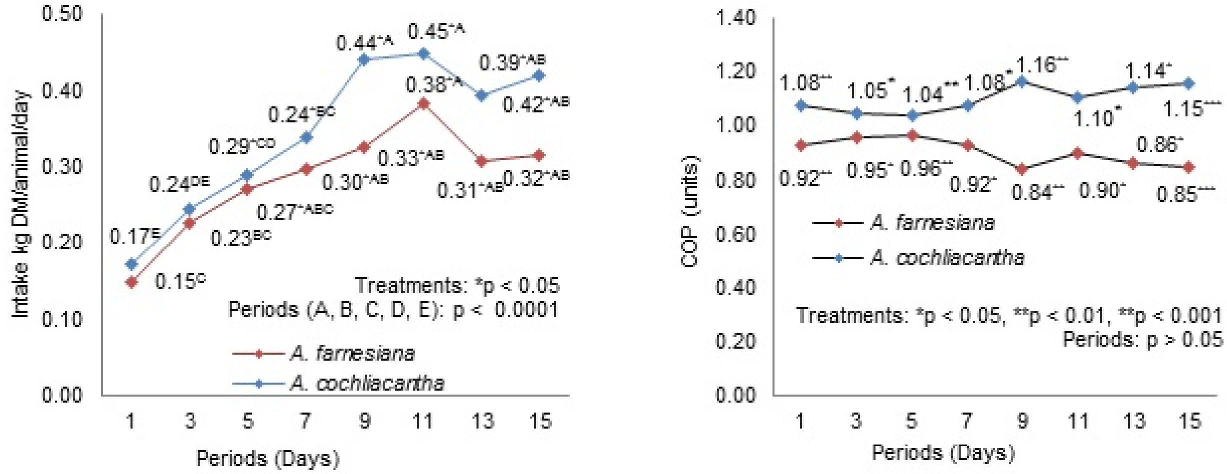

Figura 2. Palatability of two tree fruits by sheep (COP: coefficient of preference)

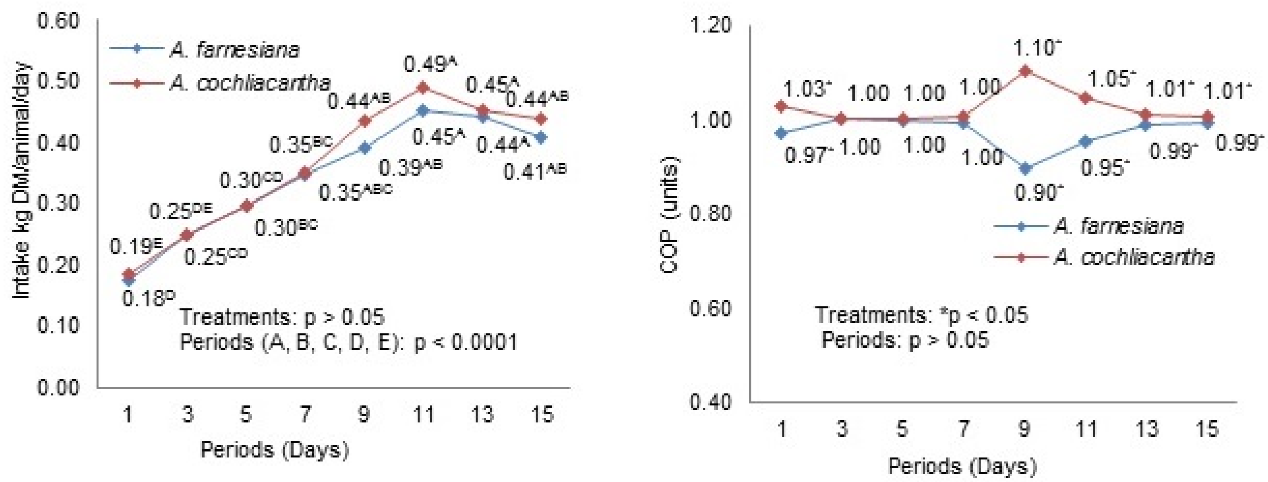

Figura 3. Palatability of two tree fruits by goats (COP: coefficient of preference)

d^{-1}) (Figure 3) . In relation to consumption dynamics during the study period, it was observed that fruit intake by goats increased significantly ($p < 0.0001$). In *A. cochliacantha* fruit, it increased from 0.19 kg DM animal^{-1} d^{-1} on the first day to 0.44 to 0.49 kg DM animal^{-1} d^{-1} between the ninth and fifteenth day. In *A. farnesiana* fruit, consumption started with 0.18 kg animal^{-1} d^{-1} and reached 0.39 to 0.45 kg DM animal^{-1} d^{-1} between the ninth and fifteenth day (Figure 3). The COP of the goats for *A. cochliacantha* fruit varied between 1.00 and 1.05 units and was higher ($p < 0.05$) than the COP they had for *A. farnesiana* fruit on the first day and between the ninth and fifteenth day only (Figure 3). In terms of COP dynamics during the study period, it was observed that fruit intake by goats by tree species did not differ ($p > 0.05$) (Figure 3). In goats the differences in the COP (Figure 3) may indicate their tendency to prefer *A. cochliacantha* fruit due to its protein and detergent fiber contents (Table 1), behavior similar to that reported by Alonso *et al.* (2008) and Olivares *et al.* (2013a). In goats the consumption of *A. cochliacantha* and *A. farnesiana* fruits was similar (Figure 3), which indicates their ability to adapt to eating foods with higher total phenol and condensed tannin contents and regulate their nutritional needs to the intake of diversified feeds (Torres *et al*. 2008, Olivares *et al*. 2013b).

It is important to analyze the CT and TP content of fruit (< 5 %) as it indicates its potential as feed for ruminants (Table 1); this is because reports indicate that such secondary compounds in higher amounts affect the rumen microbial population, inactivate enzymes in the rumen, precipitate proteins and carbohydrates from the diet and consequently cause poor digestion of feed, leading to increased nitrogen excretion in the feces (Patra and Saxena 2011, Lorentz *et al*. 2013, Hatew *et al*. 2014). They can also affect the health of the animal by causing hemolysis and increased methemoglobin in the blood, which can lead to the death of the animal (Mueller-Harvey 2010)

Variation among ruminants in dry matter intake of the fruits of different trees has demonstrated the usefulness of preference tests in ruminants for reporting differences in palatability of feed, where there are factors of interaction inherent to the animal and to the organoleptic properties of the feeds given to it due to their chemical compounds (Mokoboki *et al*. 2011, Olivares *et al*. 2013b).

It is concluded that the differences in the consumption of fruits and in the COP between ruminant animals were determined by the *in vitro* digestibility of DM and OM, as well as the content of CP, ADF, NDF and CT. The fruit of P. dulce was the most palatable for calves, whereas the fruit of *A. cochliacantha* was the most palatable for sheep and goats, which adapted to consuming fruit with higher levels of CT due to the physiological and chemical characteristics of their salivary secretions. The three fruits have potential as feed for ruminants in the tropics because of their low content (< 5.0 %) of secondary compounds (CT and TP) and a CP content greater than 8.0 %.

ACKNOWLEDGEMENTS:

The authors thank SEMILLA-UAGro for funding this research project, which enabled the students involved to fulfill their degree requirements.

LITERATURA CITADA

Alonso DMA, Torres AJFJ, Sandoval CCA, Hoste H, Aguilar CAJ, Capetillo LCM (2008) Is goats' preference of forage trees affected by their tannin or fiber content when offered in cafeteria experiments. Animal Feed Science and Technology 141: 36-48.

Alonso DMA, Torres AJFJ, Sandoval CCA, Hostec H, Aguilar CAJ, Capetillo LCM (2009) Sheep preference for different tanniniferous tree fodders and its relationship with *in vitro* gas production and digestibility. Animal Feed Science and Technology 151: 75-85.

AOAC, 2000. Official methods of analisis 17th ed. Association of Offician Analytical Chemist. Arlington, VA. USA. 74p.

Fragoso LC (1990) Ubicación geográfica del Municipio de Cutzamala de Pinzón. Monografía del Estado de Guerrero, sur amate de mar y montaña. SEP, México, DF. 237p.

Gregorini P, Villalba JJ, Provenza FD, Beukes PC, Forbes JM (2015) Modelling preference and diet selection patterns by grazing ruminants: a development in a mechanistic model of a grazing dairy cow, MIND. Animal Production Science 55: 360-375.

Hatew B, Hayot-Carbonero C, Stringano E, Sales LF, Smith LMJ, Mueller-Harvey I, *et al*. (2014) Diversity of condensed tannin structures affects rumen *in vitro* methane production in sainfoin (*Onobrychis viciifolia*) accessions. Grass and Forage Science 70: 1-17.

Herrero M, Jessop NS (1996) Relationship between *in vitro* gas production and neutral detergent fiber disappearance in three tropical grasses. Animal Science 62: 682-692.

Lorenz MM, Alkhafadji L, Stringano E, Nilsson S, Mueller-Harvey I, Udena P (2014) Relationship between condensed tannin structures and their ability to precipitate feed proteins in the rumen. Journal of the Science of Food and Agriculture 94: 963-968.

Mlambo V, Sikosana JLN, Smith T, Owen E, Mould FL, Mueller-Harvey I (2011) An evaluation of NaOH and wood ash for the inactivation of tannins in *Acacia nilotica* and *Dichrostachys cinerea* fruits using an *in vitro* rumen fermentation technique. Tropical Agriculture 88: 44-54.

Mokoboki HK, Ndlovu LR, Malatje MM (2011) Intake and relative palatability indices of acacia species fed to sheep and goats. Agroforestry Systems 81: 31-35.

Mueller-Harvey I (2010) Unravelling the conundrum of tannins in animal nutrition and health-Review. Journal of the Science of Food and Agriculture 86: 2010-2037.

Olivares PJ, Aviles NF, Albarran PB, Castelan OOA, Rojas HS (2013a) Use of three fodder trees in the feeding of goats in the subhumid tropics in Mexico. Tropical Animal Health and Production 45: 821-828.

Olivares PJ, Avilés NF, Albarrán PB, Castelán OOA, Rojas HS (2013b) Nutritional quality of *Pithecellobium dulce* and *Acacia cochliacantha* fruits, and its evaluation in goats. Livestock Science 154: 74-81.

Olivares PJ, Aviles NF, Rojas HS, Albarran PB, Castelan OOA (2011) Identification, uses and measurement of fodders legumes trees in south farmers of the States of Mexico. Tropical and Subtropical Agroecosystems 14: 739-748

Patra AK, Saxena J (2011) Exploitation of dietary tannins to improve rumen metabolism and ruminant nutrition. Journal of the Science of Food and Agriculture 91: 24-37.

Rojas-Hernandez S, Olivares-Perez J, Elghandour MMMY, Cipriano-Salazar M, Avila-Morales B, Camacho-Díaz LM, *et al.* (2015) Effect of polyethylene glycol on *in vitro* gas production of some non-leguminous forage trees in tropical region of the south of Mexico. Agroforestry System 89: 735-742

Seresinhe T, Madushika SAC, Seresinhe Y, Lal PK, Ørskov ER (2012) Effects of Tropical High Tannin Non Legume and Low Tannin Legume Browse Mixtures on Fermentation Parameters and Methanogenesis Using Gas Production Technique. Asian-Australian Journal of Animal Science 25: 1404-1410.

Statistical Analysis System (SAS) (2002) SAS/STAT. In: Guide for Personal Computers Version Ver 9.0. Institute Inc. Cary, NC, USA. 956p.

Torres JFJ, Alonso DMA, Hoste H, Sandoval CCA, Aguilar CAJ (2008) Positive and negative effects in goat production arising from the intake of tannin rich forage. Tropical and Subtropical Agroecosystems 9: 83-90.

Van Soest PJ, Robertson JB, Lewis BA (1991) Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74: 3583-3592.

Van Soest PJ (1994) Nutritional Ecology of the Ruminant. Cornell University Press, Ithaca, NY, USA. pp: 297-300.

Waterman PG, Mole S (1994) Analysis of phenolic plant metabolites. Blackwell Scientific Publications, London. Ed. Oxford. 238p.