https://doi.org/10.32854/agrop.v13i12.1889

Chemical Composition and Digestibility of Six Species of Legumes (Fabaceae)

Sosa-Montes, Eliseo[1]; Mendoza-Pedroza, Sergio Iban[2*]; Perpetuo Álvarez Vázquez[3]; Domínguez-Martínez Pablo Alfredo[4]; Ricardo-Barcena Gama[2], Salazar González Jessica Lorena[5]

[1]Universidad Autónoma Chapingo, Departamento de Zootecnia. Chapingo, Estado de México. [2]Colegio de Postgraduados, Campus Montecillo, Montecillo, Texcoco, Estado de México. [3]Universidad Autónoma Agraria Antonio Narro-Unidad Saltillo, México. [4]Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Campo Experimental Valle del Guadiana. Durango, México. [5]Universidad Mesoamericana de Puebla, Plantel Sur. Totimehuacan. Puebla, Puebla. México.

***Corresponding Author**: sergiomp@colpos.mx

ABSTRACT

Objectives: To determine the chemical composition and *in vitro* digestibility of *Acacia angustissima*, *Dalea* spp., *Desmodium* spp., *Leucaena leucocephala*, *Phaseolus vulgaris* and *Tephrosia vicioides* (Fabaceae).

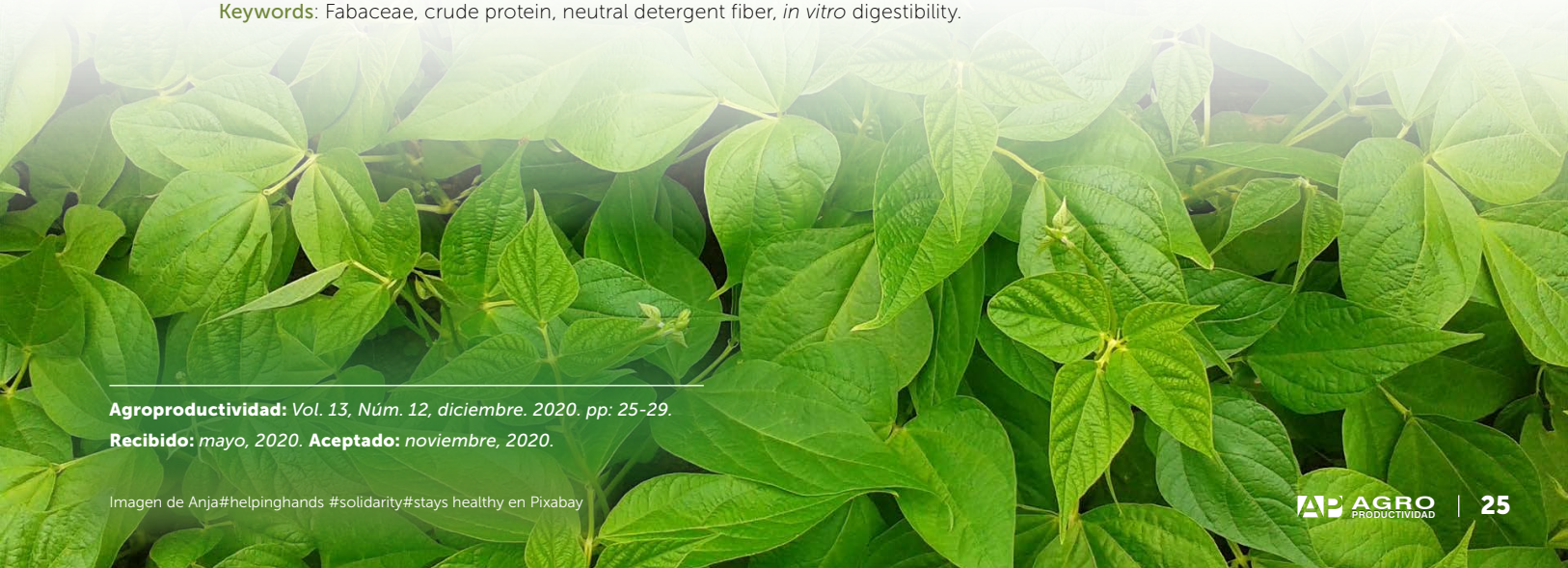
Design/Methodology/Approach: Crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude lignin (CL), cellulose (Cel), hemicellulose (Hcel), cellular content (CC) and *in vitro* dry matter digestibility (IVDMD) were determined. The design was completely random with three replicates. The variables were correlated by pairs and the means of the species were compared with the Tukey's test ($P<0.05$).

Results: *Dalea* spp. had the highest crude protein (17.7%), followed by *A. angustissima* (15.9%) and *L. leucocephala* (14.1%). *A. angustissima* (73.2%), *Dalea* spp. (74.9%) and *P. vulgaris* (77.5%) showed the highest IVDMD. *L. leucocephala*, *Tephrosia vicioides* and *Desmodium* spp. showed the lowest values of CP (14.1, 11.8 and 12.3%, respectively) and IVDMD (70.4, 70.2 and 64.9%, respectively). *Desmodium* spp. showed high levels of NDF (59.2%), ADF (41.4%), CL (17.5%), Cel (29.7%) and Hcel (17.8%) ($P<0.05$). The IVDMD showed positive correlation with CC and negative correlations with NDF, CL, and Hcel ($P<0.05$).

Study Limitations/Implications: *Desmodium* spp. showed high content of CL and low values of CP and IVDMD, therefore supplements should be added when used this legume in animal feed.

Findings/Conclusions: *Dalea* spp. showed low levels of lignin and high levels of protein and digestibility, making it possible to use it as feed for ruminants.

Keywords: Fabaceae, crude protein, neutral detergent fiber, *in vitro* digestibility.



Agroproductividad: *Vol. 13, Núm. 12, diciembre. 2020. pp: 25-29.*
Recibido: *mayo, 2020.* **Aceptado:** *noviembre, 2020.*

Imagen de Anja#helpinghands #solidarity#stays healthy en Pixabay

INTRODUCTION

Forages are the main source of food for livestock, they can grow naturally, be sown and established for direct grazing, and they can be acquired through manual or mechanical cutting (Santos *et al*., 2015). The challenge for livestock producers lies in improving production in order to cover the demand and conserve natural resources and the environment (Giraldo, 1999). An important factor in animal production is the composition and quality of the forages that make up the diet (Rojas *et al*., 2005). Therefore it is important to know the forage resources available in a specific region, in order to develop systems that are more sustainable and productive (Lascano and Ávila, 1991). Legumes have nutritional quality and are cultivated as a protein bank in strips or in association with grasses (Poaceae) (Hess and Lascano, 1997). Since they have a short growing cycle, they can be used as emergency crops of high quality (Reta *et al*., 2013). Moreover, forage Fabaceae are of better quality than grasses due to better digestibility, which is related to lower fiber content, and most of their digestible energy comes from soluble cell constituents, rather than from fiber (Buxton *et al*., 1996). Although Fabaceae have higher protein content, there is little information in the literature reviewed about its nutritional value to justify including it in a diet, as either a principal or secondary component, in order to improve its efficiency for use by livestock (González and Cáceres, 2002; García and Medina, 2006). The objective was to determine the chemical composition and *in vitro* digestibility of six Fabaceae forage species native to the state of Morelos, Mexico.

MATERIALS AND METHODS

Six species of the Fabaceae family were used, and they were collected during the same time of year in several municipalities in Morelos, Mexico. Leaves, stems and fruits (aerial part) were collected in order to carry out a botanical identification up to genus (Table 1).

The samples were dried at a constant weight in an oven at 55 °C, and then each sample was analyzed in triplicate in order to determine the crude protein (CP), ether extract (EE) and ash (Ash) content or proximate analysis (AOAC, 1990), and the Van Soest *et al*. (1991) analysis: neutral detergent fiber (NDF), acid detergent fiber (ADF), crude lignin (CL), cellulose (Cel), hemicellulose (Hcel), cellular content (CC) and *in vitro* dry matter digestibility (IVDMD) with the methodology described by Giraldo *et al*. (2007). The study was carried out in the Animal Nutrition Laboratory of the Animal Science Department, in Texcoco, Mexico.

The variables of chemical composition and IVDMD were subjected to an analysis of variance (ANOVA) with the completely randomized experimental design. The means were compared with the Tukey's test ($P<0.05$). Also, a correlation analysis was carried out by pairs of variables ($P<0.05$) using the SPSS (2011) software.

RESULTS AND DISCUSSION

The results are expressed in dry basis (Table 2 and 3), and Table 4 shows the correlation between pairs of variables studied. *Desmodium* spp. showed the lowest IVDMD, CP and CC. Low CP values are associated with low levels of CC, and low CC levels are associated with low IVDMD. Inversely, Dalea spp. showed the highest IVDMD associated with elevated CP content. *Acacia angustissima* showed similar IVDMD values as *Dalea* spp., and slightly lower CP levels. Based on these results, it was inferred that with higher CP content there is higher IVDMD. These results can be explained by the following positive correlations: IVDMD *vs* CC and CC *vs* CP (Table 4). The positive correlation (0.96) between IVDMD (65.3%) and CP (22.5%) has been demonstrated ($P<0.01$) in vetch by Gezahagn *et al*. (2014).

Desmodium spp. showed higher content of all fibrous components (NDF, ADF, CL, Cel and Hcel; Table 2) and lower IVDMD (Table 3). *Dalea* spp. showed the lowest

Table 1. Species and collection sites in the state of Morelos, Mexico.

Species	Municipality	Collection site
Acacia angustissima	Ticuman	Tlaltizapan-Yautepec Highway, 5 km from Ticuman.
Dalea spp.	Tlalquiltenango	At 200 m from the community of San Pablo, Tlalquiltenango
Desmodium spp.	Nepoapulco	Next to the bridge "El Vigía".
Leucaena leucocephala	Tepoztlán	"El Puente" place, in the community of Santa Catarina, Tepoztlán
Phaseolus vulgaris	Nepoapulco	Before the bridge "El Vigía", towards Mexico City.
Tephrosia vicioides	Totolapan	Tlayacapan-Atlatlahuacan highway, after the deviation towards Mexico City

Table 2. Fibrous components of six species of legumes (Fabaceae) from Morelos, Mexico.

Species	% Dry basis				
	NDF	ADF	CL	Cel	Hcel
Acacia angustissima	42.9^{c}	29.0^{c}	15.6^{ab}	13.4^{b}	13.9^{b}
Dalea spp.	50.4^{b}	41.3^{a}	11.6^{c}	29.7^{a}	9.1^{c}
Desmodium spp.	59.2^{a}	41.4^{a}	17.5^{a}	29.7^{a}	17.8^{a}
Leucaena leucocephala	50.5^{b}	30.9^{c}	18.8^{a}	12.0^{b}	19.6^{a}
Phaseolus vulgaris	49.5^{b}	38.1^{b}	12.7b^{c}	25.4^{a}	11.4^{c}
Tephrosia vicioides	59.0^{a}	40.0a^{b}	13.4b^{c}	26.6^{a}	19.0^{a}
Standard error of mean	1.38	1.22	0.69	1.96	0.98

$^{a, b, c}$ Different letters in the same column indicate significant differences (P<0.05). NDF: neutral detergent fiber, ADF: acid detergent fiber, CL: crude lignin, Cel: cellulose, Hcel: hemicellulose.

Table 3. *In vitro* digestibility and non-fibrous components of six species of legumes (Fabaceae) from Morelos, Mexico.

Species	% Dry basis				
	IVDMD	CP	CC	EE	Ash
Acacia angustissima	73.2^{ab}	15.9^{b}	57.1^{a}	2.7^{d}	4.2^{d}
Dalea spp.	74.9^{ab}	17.7^{a}	49.6^{b}	3.6^{b}	6.7^{a}
Desmodium spp.	64.9^{c}	12.3^{d}	40.8^{c}	3.0^{c}	4.7^{c}
Leucaena leucocephala	70.4^{b}	14.1^{c}	49.5^{b}	4.2^{a}	6.7^{a}
Phaseolus vulgaris	77.5^{a}	11.7^{d}	50.5^{b}	3.7^{b}	6.0^{b}
Tephrosia vicioides	70.2^{b}	11.8^{d}	41.0^{c}	2.8c^{d}	6.1^{b}
Standard error of mean	1.04	0.55	1.38	0.15	0.23

$^{a, b, c, d}$ Different letters in the same column indicate significant differences (P<0.05). IVDMD: *in vitro* dry matter digestibility, CP: crude protein, CC: cellular content, EE: ether extract, Ash: ashes.

value of CL and Hcel (Table 2 and 3), associated with high levels of IVDMD. *Acacia angustissima* showed low amounts of NDF, ADF, Cel and Hcel, and higher IVDMD than *Desmodium* spp. This indicates a negative correlation between IVDMD and NDF, CL and Hcel (Table 4). These negative correlations by pairs (P<0.05) between fibrous components and IVDMD were reported by Ortíz-Domínguez *et al*. (2017) in pods of different Fabaceae (previously known as legumes) for IVDMD *vs* NDF (−0.848) and for IVDMD *vs* CL (−0.957).

Tephrosia vicioides showed similar NDF, ADF, CL, Cel and Hcel levels (Table 2) as *L. leucocephala* and its IVDMD values were also similar (Table 3). The elevated levels of IVDMD showed by *P. vulgaris* are probably due to its low values of CL and Hcel (Table 2). The negative correlations in Table 4 indicate that lower CL *vs* higher IVDMD (−0.601), and lower Hcel *vs* higher IVDMD (−0.713). At higher levels of NDF, there were high levels of ADF, Hcel or Cel. With higher levels of the fiber variables (NDF, CL or Hcel), there are lower values of IVDMD, CP or CC. Therefore, *Desmodium* spp., which resulted with high levels of NDF, ADF, CL, Cel and Hcel, produced the lowest values of IVDMD, CP and CC. At low values of CL and Hcel, there were high levels of IVDMD; therefore, *Dalea* spp., which produced low values of CL and Hcel, produced high levels of IVDMD.

Comparison of CP and IVDMD values of this study with those from the literature

Acacia angustissima **(CP: 15.9%, IVDMD: 73.2%)**. Ncube *et al*. (2017) reported 23.4% of CP in *A. angustissima*. Aganga *et al*. (1997) found 12.52%, 17.14%, 13.67% and 12.74% of CP for *A. robusta*, *A. nigrescens*, *A. karoo*, and *A. rehmanniana*, respectively. Castrejón *et al*. (2017)

Table 4. Significant correlations between the response variables.

	IVDMD	CP	CC	EE	NDF	ADF	CL
IVDMD	1						
CC	0.587*	0.585*	1				
Ash				0.75*			
NDF	−0.587*	−0.585*			1		
ADF			−0.725**		0.725**	1	
CL	−0.601*						1
Cel			−0.579*		0.579*	0.884**	−0.79**
Hcel	−0.713**	−0.526*	−0.513*		0.513*		0.662**

The non-fibrous components are IVDMD: *in vitro* dry matter digestibility, CP: crude protein, CC: cellular content, EE: ether extract, Ash: ashes. The fibrous components are NDF: neutral detergent fiber, ADF: acid detergent fiber, CL: crude lignin, Cel: cellulose, Hcel: hemicellulose. (*): P<0.05, (**): P<0.01.

reported 16.8% of CP and 64.3% of IVDMD for *Acacia farnesiana*. Goel *et al*. (2015) found IVDMD values between 56.9% and 65.7% for *Acacia nilotica*. Ortíz-Domínguez *et al*. (2017) found IVDMD values of 44.5% for *Acacia pennatula*.

***Dalea* spp. (CP: 17.7%, IVDMD: 74.9%)**. Huang *et al*. (2015) reported 13.3% (N×6.25) of CP in *Dalea purpurea*, and Peng *et al*. (2020) reported 70.5% of IVDMD in *Dalea purpurea*.

***Desmodium* spp. (CP: 12.3%, IVDMD: 64.9%)**. Tessema and Baars (2006) reported CP values of 23.1% in *Desmodium uncinatum*, and Chamorro *et al*. (2005) reported an average of 76.4% of IVDMD in *Desmodium barbatum*.

***Leucaena leucocephala* (CP: 14.1%, IVDMD: 70.4%)**. Gutiérrez *et al*. (2005), found 25% of CP in *Leucaena leucocephala*. Castrejón *et al*. (2017) reported 17.6% of CP and 74.9% of IVDMD for *Leucaena leucocephala* in Paso del Toro, Veracruz, six weeks after regrowth. Ortíz-Domínguez *et al*. (2017) found 46.4% of IVDMD for *Leucaena leucocephala*.

***Phaseolus vulgaris* (CP: 11.7%, IVDMD: 77.5%)**. Alatorre-Hernández *et al*. (2018) found 11.7% of CP and 49.4% of IVDMD for *Phaseolus acutifolius*. Vojtíšková and Kráčmar (2013), found 41.0% of IVDMD in *Phaseolus vulgaris*.

***Tephrosia vicioides* (CP: 11.8%, IVDMD: 70.2%)**. Ojo *et al*. (2012) reported 13.6% of CP for *Tephrosia bracteolata* 20 weeks after sowing, and Chamorro *et al*. (2005) reported 80.5% of IVDMD in *Tephrosia cinerea*, similar and superior when compared to the values reported in this study.

In general, the majority of the values of the variables in this study were 10% higher or lower than those in the literature consulted. For example, Tessema and Baars (2006) found values of NDF (46.50%) and ADF (35.4%) in *Desmodium uncinatum*, which are lower than those reported in this study (Table 2). For the Ash variable, Ncube *et al*. (2017) found values of 4.3% in *Acacia angustissima*, and Ojo *et al*. (2012) found values of 5.3% in *Tephrosia bracteolata*, similar to those in this study (Table 3). Ojo *et al*. (2012) reported 13.6% of CL and 2.2% of EE in *Tephrosia bracteolata*. García *et al*. (2008) reported ADF levels of 25.4% for *Leucaena* spp., while in this study 30.9% was obtained (Table 2). In most cases the values of CL and Ash in the present study were similar; those of EE, CP and NFD were lower, and ADF and IVDMD were higher than those reported in the literature for the same species of Fabaceae.

CONCLUSIONS

Dalea spp. was the best forage species. With *Desmodium* spp. high supplementation with protein and non-fibrous carbohydrates should be used; and with *Dalea* spp. supplementation could be less or none. For the rest of the species that were not in the extreme positions, moderate supplementation could be used.

REFERENCES

Aganga, A.A., Tsopito, C.M., & Adogla-Besssa, T. (1997). Potencial alimenticio para los rumiantes de las especies de Acacia de Botswana. Archivos de Zootecnia. 47 (180): 659-668.

Alatorre-Hernández, E., Guerrero-Rodríguez. J.D., Olvera-Hernández, J.I., Aceves-Ruíz, E., Vaquera-Huerta, H., & Vargas-López, S. (2018). Productividad, características fisicoquímicas y digestibilidad *in vitro* de leguminosas forrajeras en trópico seco de México. Revista Mexicana de Ciencias Pecuarias. 9(2): 296-315.

AOAC (1990). Methods of analysis of the association of official analytical chemists. (15th Ed.). Arlington. VA: Association of Official Analytical Chemists. 771 p.

Buxton, D.R., Mertens, D.R., & Fisher, D.S. (1996). Forage quality and ruminant utilization. In: cool season grasses. Agronomy monograph. American Society of Agronomy. 1: 229-266.

González, E., & Cáceres, O. (2002). Valor nutritivo de árboles, arbustos y otras plantas forrajeras para los rumiantes. Pastos y Forrajes 25 (1): 15-20.

Castrejón, P.F.A., Corona, G.L., Rosales, M.R., Martínez, P.P., Lorenzana, M.A.V., Arzate, V.L.G., *et al*. 2017. Características nutrimentales de gramíneas, leguminosas y algunas arbóreas forrajeras del trópico mexicano: fracciones de proteína (A, B1, B2, B3 y C), carbohidratos y digestibilidad *in vitro*. (1a Ed.). México: Facultad de Medicina Veterinaria y Zootecnia (UNAM). 172 p.

Chamorro, D., Carulla, J. E., & Cuesta, P. (2005). Degradación microbiana *in situ* de tejidos foliares de gramíneas y leguminosas y su relación con indicadores de calidad nutricional. Ciencia y Tecnología Agropecuaria. 6(1): 100-116. Disponible en: https://www.redalyc.org/articulo.oa?id=4499/449945018012

García, D.E., & Medina, M.G. (2006). Composición química, metabolitos secundarios, valor nutritivo y aceptabilidad relativa de diez árboles forrajeros. Zootecnia Tropical. 24(3): 233-250. Recuperado el 17 de abril de 2020 de http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S0798-72692006000300004&lng=es&tlng=es

García, D., Wencomo, H., Medina, M., Cova, L., González, M., Pisan, P., Domínguez, C., & Baldizán A. (2008). Variación interespecífica de la calidad nutricional de diecisiete accesiones de *Leucaena*. Avances en Investigación Agropecuaria. 12(1):67-80.

Gutiérrez, O., Delgado, P., Oramas, A., & Cairo, J. (2005). Consumo y digestibilidad de materia seca y nitrógeno total en vacas en pastoreo durante la época de lluvias, con bancos de proteína y sin ellos. Revista Cubana de Ciencia Agrícola. 39(4): 593-598.

Gezahagn K., Getnet A., Alemayehu M. & Fekede F. (2014). Forage nutritive values of vetch species and their accessions grown under nitosol and vertisol conditions in the central highlands of Ethiopia. Livestock Research for Rural Development. 26(1), Article 20. Retrieved April 17, 2020, from http://www.lrrd.org/lrrd26/1/kebe26020.htm

Giraldo, V.L.A. (1999). Potencial de la arborea guácimo (*Guazuma ulmifolia*), como componente forrajero en sistemas silvopastoriles. Universidad Nacional de Colombia. Agroforestería para la Producción Animal en Latinoamérica. 1: 201-215.

Giraldo, L.A., Gutiérrez, L.A., & Rúa, C. (2007). Comparación de dos técnicas *in vitro* e *in situ* para estimar la digestibilidad verdadera en varios forrajes tropicales. Revista Colombiana de Ciencias Pecuarias. 20: 269-279.

Goel, G., Raghav, M., Beniwal, V., & Puniya, A.K. (2015). Anaerobic degradation of tannins in *Acacia nilotica* pods by *Enterococcus faecalis* in co-culture with ruminal microbiota. Journal of General Applied Microbiology. 61(1): 31–33. DOI: 10.2323/jgam.61.31

Hess, D.H., & Lascano, C.E. (1997). Comportamiento del consumo de forrajes por novillos en pasturas de gramínea sola y asociada con una leguminosa. Pasturas tropicales. 19 (2): 12-20.

Huang, Q.Q., Jin, L., Xu, Z., Barbieri, L.R., Acharya, S., Hu, T.M., Mcallister, T.A., Stanford, K. & Wang, Y. (2015). Effects of purple prairie clover (*Dalea purpurea* Vent.) on feed intake, nutrient digestibility and faecal shedding of *Escherichia coli* O157: H7 in lambs. Animal Feed Science and Technology. 207: 51-61. DOI: 10.1016/j.anifeedsci.2015.06.009DOI: 10.1016/j.anifeedsci.2015.06.009

Lascano, C.E., & Avila P. (1991). Potencial de producción de leche en pasturas solas y asociadas con leguminosas adaptadas a suelos ácidos. Pasturas Tropicales. 13(3): 2-10.

Ncube, S., Halimani, T. E., Mwale, M., & Saidi, P. T. (2017). Effect of *Acacia angustissima* leaf meal on the physiology of broiler intestines. Journal of Agricultural Science. 9(2): 53-62.

Ojo, V.O.A., Aina, A.B.J., Arigbede, O.M., Olanite, J.A., Amole, T.A., Anele, Y.U., Dele, P.A., Adeoye, S.A., & Idowu, O.J. (2012). EValuation of the agronomic performance and nutritive values of *Tephrosia bracteolata* Guill. & Perr. and *Gmelina arborea* Roxb prunnings at different stages of growth. Journal of Agricultural Science and Environment. 12(2):15-25.

Ortíz-Domínguez, G., Ventura-Cordero, J., González-Pech, P., Torres-Acosta, J.F.J., Capetillo-Leal, C.M., & Sandoval-Castro, C.A. (2017). Nutritional value and *in vitro* digestibility of legume pods from seven trees species present in the tropical deciduous forest. Tropical and Subtropical Agroecosystems. 20: 505-510.

Peng K., Gresham, G.L., McAllister, T.A., Xu, Z., Iwaasa, A., Schellenberg, M., Chaves, A. V., & Wang, Y. (2020). Effects of inclusion of purple prairie clover (*Dalea purpurea* Vent.) with native cool-season grasses on *in vitro* fermentation and *in situ* digestibility of mixed forages. Journal of Animal Science and Biotechnology. 11: 23 https://doi.org/10.1186/s40104-019-0418-6

Reta, S.D.G., Castellanos, G.P.C., Olague, R.J., Quiroga, G.H.M., Serrato, C.J.S., & Gaytán, M.A. (2013). Potencial forrajero de cuatro especies leguminosas en el ciclo de verano en la Comarca Lagunera. Revista Mexicana de Ciencias Agrícolas 4 (5): 639-671.

Rojas, H.S., Olivares, P.J., Jiménez, G.R., & Hernández, C.E. (2005). Manejo de praderas asociadas de gramíneas y leguminosas para pastoreo en el trópico. Revista Electrónica de Veterinaria. 6: 1-19.

Santos, P.J., Castellón, J., & Guharay, F. (2015). Manual de conservación de forrajes. Managua, Nicaragua. Managua, Nicaragua. Editorial Catholic Relief Services. 9-11 pp.

SPSS, Statistical Package for the Social Sciences. (2011). Institute. SPSS-X. User's Guide. Version 8, Chicago IL. USA.

Tessema, Z., & Baars, R.M.T. (2006). Chemical composition, dry matter production and yield dynamics of tropical grasses mixed with perennial forage legumes. Tropical Grasslands. 40: 150 –156.

Van Soest, P.J., Roberton, 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(10): 3583-3597.

Vojtíšková, P., & Kráčmar, S. (2013). Crude protein, fibre and phytic acid *in vitro* digestibility of selected legume and buckwheat samples. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis. 61 (1): 227-232.