Article

# Quality of organic and inorganic fodder of corn and Yorimón bean

Miguel Ángel Gallegos-Robles[1]
J. Guadalupe Luna-Ortega[2§]
Magdalena Galindo-Guzmán[2]
María Gabriela Cervantes-Vázquez[1]
Daniela Monserrat Sánchez-Pérez[2]
Uriel González-Salas[1]

[1]Juarez University of the State of Durango. Highway Gómez Palacio-Tlahualilo km 32, ejido Venecia, Gómez Palacio, Durango, Mexico. ZC. 34371. (garoma64@hotmail.com; cevga@hotmail.com; u.gonzalez@ujed.mx). [2]Polytechnic University of the Laguna Region. Road to the old boarding school in Santa Teresa, Saint Peter of the Colonies, Coahuila, Mexico. ZC. 27942. (magda.galindo@uprl.edu.mx; danielaspsl38@gmail.com).

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

## Abstract

The objective of this study was to produce organic fodder based on corn and Yorimón bean as an alternative to conventional fodders in the Lagunera Region. The experiment was conducted in the spring-summer cycle from April to August 2017. In each useful plot, three corn plants and three Yorimón bean plants were harvested, which were finely chopped and mixed to form a balanced compound of which one kilogram was used for bromatological analyses. A randomized block design with four repetitions was used. In the CP of organic and inorganic fodders, no significant differences were observed ($p > 0.05$) and the values found were within the optimal values for cows in production. CP correlated positively with TDN and NEL ($p < 0.01$). The quality of the fodder combined between corn and Yorimón bean showed that it is an alternative to conventional fodders.

**Keywords:** high yield, inorganic fertilization, organic fertilization.

Reception date: November 2021
Acceptance date: January 2022

# Introduction

In Mexico, the Comarca Lagunera is the main dairy basin of the country. It produces more than 2 433 million liters of milk annually from a herd of more than 465 thousand head of cattle (SIAP, 2017a; 2017b). There is a need to seek for new fodder alternatives to reduce production costs, lower water consumption and maintain or improve the nutritional quality of fodder, mainly for dairy cattle, given that the largest dairy basin in the country is in the Comarca Lagunera. This makes it necessary to carry out studies in one of the most demanded crops such as forage corn (*Zea mays* L.) in association with other species, such as Yorimón bean [*Vigna unguiculata* (L.) Walp], in order to meet the food needs in the diet of dairy cows, given its high productivity and quality in green and silage (LACTODATA, 2011).

It is important to seek better alternatives in terms of genotypes that ensure high fodder yields considering a higher leaf-stem ratio, green corn cob-plant ratio, high dry matter production and higher nutritional quality (Clark *et al*., 2002). Driving the development of science towards new production approaches that ensure greater efficiency to face the growing problems of food security has created the need to seek sustainable alternatives to offer animal feed at lower cost and higher productivity (FAO, 2017). Within these feeds are fodders, which can be used in green, hay or silage. The characteristics of a good fodder include nutrient content, digestibility, palatability, yield, among others.

Corn is an ideal crop for silage due to its high content of available carbohydrates, its high yield of green matter and its low cost of production (Ahlgren, 1949; Inchausti and Tagle, 1987). Corn is the most widely produced cereal in the world, it is one of the most important sources of feed for livestock (Serna, 2006). Yorimón bean is an herbaceous legume with an erect, semi-erect and creeping growth habit, which grows between 50 and 100 cm; well adapted to different soils and climates (Cook *et al*., 2005). It has its origin in Asia and the centers of genetic diversity are located in Africa and India (Phansak *et al*., 2005); however, it is sown in several countries of the African, European and American continents, the latter being where it is most consumed (Apáez *et al*., 2009).

As a legume with a high nutritional content, it is important to evaluate it, since a good percentage of the world population feeds on it (Singh *et al*., 2003; Lewis *et al*., 2005). It is grown in more than two-thirds of developing countries as a growing partner with major cereal crops (Agbogidi, 2010). Yorimón bean has several uses, among which green manure (Beltrán-Morales *et al*., 2009), cover, hay, silage, concentrate and human food can be mentioned, as reported by López and Bressani (2008); Mayz *et al*. (2010); Vargas *et al*. (2012), in addition to being used in cattle feed (Vendramini *et al*., 2012), it is a legume that for many years has been used as fodder for birds and pigs (Murillo-Amador *et al*., 2000; Castro *et al*., 2002) and poultry (Sarmiento *et al*., 2011).

This is because it is one of the most adaptable, versatile and nutritious crops, with a high protein content and high digestibility, studies such as those of Ramakrishnan *et al*. (2005); Apáez *et al*. (2009). The species adapts easily to different stressful conditions (Gómez *et al*., 2013); however, it is necessary to consider factors such as soil type, climate, competition with weeds, as mentioned by Shindoi *et al*. (2012); Cardona *et al*. (2013), and the variety used (Ávila *et al*., 2010). The objective of this study was to seek for new alternatives of organic fodder based on Yorimón bean and corn, seeking to maintain the quality of the fodder, mainly for dairy cattle.

## Materials and methods

The study was carried out in the experimental field of the Polytechnic University of the Laguna Region, in the ejido of Santa Teresa, municipality of San Pedro de las Colonias, Coahuila de Zaragoza, Mexico, located in the geographical coordinates: longitude 103.355833 and latitude: 25.774722, located at an altitude of 1 020 m, its climate is dry, desert, average annual rainfall of 258 mm and average annual temperature of 21 °C (García, 1973). The experiment was conducted in the spring-summer cycle from April to August 2017.

For corn, the hybrid AN 447 (Mexican Institute of Corn UAAAN-Saltillo, Mexico) with a 95% genetic purity was used. Both crops were sown in wet soil on April 20, 2017, using alternating furrows, two furrows of corn, and then two furrows of Yorimón bean. For the furrows of corn, 10 to 12 seeds per linear meter were sown, and for Yorimón bean, 5 to 6 seeds per linear meter were sown, having a population density of 88 000 plants ha$^{-1}$ for corn and 75 000 plants ha$^{-1}$ for Yorimón bean. The size of the experimental plot was 458 m$^2$. Each useful plot consisted of four furrows of four linear meters and separation between furrows of 0.8 m for an area of 9.6 m$^2$.

At sowing, a pre-sowing irrigation was applied and subsequently three supplemental irrigations were applied every 30 days for a total irrigation sheet of 80 cm. The cut of the two crops was carried out on August 26, 2017, 130 days after sowing because the AN-447 corn is of late cycle and coincided with the maturation of the organic Yorimón bean. The treatments under study consisted of two sources of fertilization, one organic and one inorganic. Inorganic fertilization was 156.6 kg ha$^{-1}$ of N (source urea), 46 kg ha$^{-1}$ of $P_2O_5$ (source DAP), and organic fertilization was based on vermicompost, applying a dose of 15 000 kg ha$^{-1}$, which had a pH of 8, electrical conductivity of 3.1 dS m$^{-1}$, organic matter of 7.3%, $NO_3$ 6.21 mg kg$^{-1}$, phosphorus 38.2 mg kg$^{-1}$, potassium 215 mg kg$^{-1}$, calcium 39.1 mg kg$^{-1}$, Mg 1.5 mg kg$^{-1}$, Fe 20.8 mg kg$^{-1}$, Mn 4.1 mg kg$^{-1}$, Zn 1.3 mg kg$^{-1}$, Cu 0.8 mg kg$^{-1}$.

The cultural work was carried out in accordance with the technological package for the Laguna region recommended by Agroder (2012) corn production Mexico, 2010. State comparison of rainfed and irrigation modalities. The preparation of fodder samples for bromatological analyses, three corn plants and three Yorimón bean plants were harvested in each useful plot, having a proportion of 75% of corn and 25% of Yorimón bean, which were finely chopped and mixed to form a balanced compound of which a kilogram was weighed and put in a labeled paper bag to then dry in an oven with air forced at 72 °C for 24 h. The bromatological analysis of the dry samples was carried out in the laboratory of the Cooperativa Agropecuaria, SA de CV in Gómez Palacio, Durango.

The variables that were measured were: crude fiber (CF), ashes (ASH), crude protein (CP), total digestible nutrients (TDN), net energy of lactation (NEL), ethereal extract (EE), acid detergent fiber (ADF), neutral detergent fiber (NDF). The chemical analyses were carried out under the official Mexican standards, for CF the determination was made by acid and alkaline digestion, obtaining crude fiber and salts as residues, the crude fiber present is obtained by calcination, for ASH in a crucible at constant weight, 5 g of sample was added, placing it in a muffle and it was completely burned at 550 °C for 12 h, for CP it was quantified by the Kjeldahl method, where copper sulfate, as a catalyst, and sodium sulfate are used in order to increase the temperature of the mixture, accelerating digestion, once the distillation is finished and the obtained is tittered with HCl 0.1 N. The protein was obtained by quantifying the total nitrogen and multiplying it by 6.25.

The quantification of ADF was carried out as follows, 1 g of dry sample previously ground and sieved was taken, adding 100 ml of acid detergent solution, boiling for 2 h, filtering by gravity in a crucible, once finished the crucible was washed with 300 ml of hot distilled water, the residue was washed with acetone and dried in the crucible at 105 °C for 12 h, it was cooled in a desiccator and subsequently weighed.

For NDF, in the same way, 1 g of ground sample was taken, to which 100 ml of neutral detergent solution and 2 ml of amylase were added, boiling for 1 h, then vacuum filtered in a crucible, which was washed with hot water and finally washed 2 times with acetone, vacuum drying, the crucible was dried in an oven at 105 °C for 12 h, then cooled in the desiccator as a desiccant using phosphorus pentoxide and weighed to finish. A randomized block design with four repetitions was used. Data were analyzed using analysis of variance, multiple comparison of means (MSD, $\alpha$= 0.05) and Pearson correlation, with the SAS program (V 9.2).

## Results and discussion

The mean values of the fodder quality variables evaluated (Table 1), in the ethereal extract there were no significant differences between the types of fertilization ($p$> 0.05). The values observed in both organic and inorganic fodder were within normal values, which should not exceed a value of 6% since otherwise rumen function is affected. The ethereal extract is an indicator of the contribution of essential fatty acids in animal metabolism (Campos-Granados and Arce-Vega, 2016). In the variable crude fiber, significant differences were observed ($p$< 0.05), with the highest value in the inorganic treatment.

The values observed in both types of fodder in this work are within the optimal values of crude fiber required in feeds, 18% to 25% of the daily ration (Anrique, 2014). Crude fiber is important for stimulating rumen function and as a precursor to milk fat (Blanco-Callancho *et al*., 2018) (Table 1). In ash content, there were no significant differences between organic and inorganic fertilization ($p$> 0.05). The optimal ash content in fodders is about 5 and 9% for corn and legume fodder, respectively; however, values of up to 10 and 18% have also been observed in these same fodders (Hoffman, 2005).

**Table 1. Comparison of means for organic and inorganic fodder quality variables**.

| Treatment | Overall mean ± standard deviation | | MSD |
|---|---|---|---|
| | Organic | Inorganic | |
| EE (%) | 4.5 a ±0.198 | 3 a ±0.192 | 3.16 |
| CF (%) | 18.6 b ±0.94 | 20.9 a ±1.1 | 1.54 |
| ASH (%) | 13.3 a ±1.05 | 13.9 a ±1.18 | 0.85 |
| CP (%) | 14.9 a ±1.57 | 12.2 a ±2.58 | 7.4 |
| ADF (%) | 36.7 a ±1.22 | 33.3 a ±1.96 | 4.8 |
| NDF (%) | 57 a ±3.24 | 55.1 a ±5.77 | 4.4 |
| TDN (%) | 51.8 a ±1.4 | 58 a ±2.26 | 10.4 |
| NEL (Mcal $kg^{-1}$) | 1.5 a ±0.03 | 1.54 a ±0.05 | 0.04 |

EE= ethereal extract; CF= crude fiber; ASH= ashes; CP= crude protein; ADF= acid detergent fiber; NDF= neutral detergent fiber; TDN= total digestible nutrients; NEL= net energy of lactation. The values correspond to the average of data ± standard error. Subscripts with different letters indicate statistical differences (MSD, $p \leq 0.05$) in each row.

The values observed in this work are above the values considered optimal, but below the values considered high in corn and legume fodder (Table 1). Regarding crude protein, no significant differences were observed ($p > 0.05$), the values found in this work are within the recommended values for dairy cows in production (Moreno, 1982), with the value found in organic fertilization (14.9 ±1.57) being higher and both values of percentage of protein exceeded the value found by Silva *et al*. (2016). The protein needs of dairy cows depend on daily milk production and cow weight. Moreno (1982) mentions an optimal protein range of 11 to 16% for dairy cows in production.

In the variables acid detergent fiber (ADF) and neutral detergent fiber (NDF), no significant differences ($p > 0.05$) were observed between organic and chemical treatments. Acid detergent fiber is used to estimate the energy that will be obtained from the fodder (INIFAP, 2006); the ADF values found in this work exceeded by 5.3% (inorganic fodder) and 8.7% (organic fodder) the optimal value of 28% required in quality fodders (Gallegos-Ponce *et al*., 2012), which can be attributed to the degree of maturity of the crops at the time of harvest (Sha *et al*., 2016) (Table 1). Neutral detergent fiber (NDF) determines how much fodder the animal will consume and digestibility, the higher the NDF value, the lower the consumption (Arnold *et al*., 2019). Acceptable NDF values in corn hybrids are below 50% (INIFAP, 2006; Gallegos-Ponce *et al*., 2012).

The NDF values of this work exceeded the reference value by 5.1 and 7%, respectively, for inorganic and organic fertilization (Table 1). Total digestible nutrients (TDN), as a unit of expression of feed energy content, is an approximate measure of digestibility (Brautigan, 2007). The TDN variable is used as an indicator to evaluate the quality of legume or grass hays or for the allocation of fodder to groups of animals according to nutritional requirements (Carr *et al*., 2004; Strydhorts *et al*., 2008). The optimal values of TDN should be above 65%, a value that was not exceeded by the values found in this work (58.0 and 51.8%, respectively, for inorganic and organic fodder); however, they exceeded the values found by Moreno-Reséndez *et al*. (2017) (Table 1).

Net energy of lactation (NEL) is the energy used in milk production and according to the NRC (2001), a Holstein cow in production requires 1.5 to 1.8 Mcal $k^{-1}g$ of dry matter consumed. The NEL values found in this work were at the lower limit considered optimal, with the value observed in inorganic fodder being slightly better, although statistically there were no significant differences between both types of fodders. The NEL values of this work exceeded by 53 and 46% the values found by Moreno-Reséndes *et al*. (2017), who reported values of 0.98 and 1.05 Mcal $kg^{-1}$ of dry matter, respectively, for organic and inorganic fertilization (Table 1).

Pearson's correlation coefficients between quality variables (Table 2), EE correlated positively with CF ($p< 0.05$), with TDN ($p< 0.01$) and with NEL ($p< 0.01$). According to Cañas (1995), this association is appropriate since EE favors the assimilation of nutrients, gives flavor to the ration, and avoids the disintegration of the food. The variable TDN is used as an indicator to evaluate the quality of hays of legumes or grasses (Carr *et al*., 2004; Strydhorts *et al*., 2008).

**Table 2. Correlation coefficients for nutritional variables in the combined fodder of corn and Yorimón bean.**

| | EE | CF | ASH | CP | ADF | NDF | TDN | NEL |
|---|---|---|---|---|---|---|---|---|
| EE | 1 | 0.4614* | 0.013 | 0.1922 | -0.5582** | 0.0103 | 0.5583** | 0.5596** |
| CF | | 1 | 0.2065 | 0.4103* | -0.6692** | 0.2271 | 0.6693** | 0.6441** |
| ASH | | | 1 | 0.6395** | -0.2883 | 0.4815* | 0.2887 | 0.2693 |
| CP | | | | 1 | -0.7635** | 0.0086 | 0.7637** | 0.749** |
| ADF | | | | | 1 | 0.4015 | -1** | -0.9979** |
| NDF | | | | | | 1 | -0.5063* | -0.5084* |
| TDN | | | | | | | 1 | 0.9979** |
| NEL | | | | | | | | 1 |

CF= crude fiber; ASH= ashes; CP= crude protein; ADF= acid detergent fiber; NDF= neutral detergent fiber; TDN= total digestible nutrients; NEL= net energy of lactation; **= $p\leq 0.01$; *= $p\leq 0.05$.

The observed positive and significant relationship ($p< 0.01$) between NEL and CF in the obtained fodder composed of corn and Yorimón bean is considered acceptable given that the CF values were within the ranges accepted as optimal because if they had been high, a low NEL would have been expected because the CF would be considered non-digestible (Saha *et al*., 2017). Regarding the positive and significant relationship ($p< 0.01$) between NEL and CP in the fodder obtained, given that CP was within the optimal range, it is considered sufficient to support the needs of growth, maintenance, reproduction and lactation (Saha *et al*., 2017).

Since TDN is a measure of a food's energy value, the positive and significant association ($p< 0.01$) with NEL indicates an increase in digestible energy as TDN increases (Jayanegara *et al*., 2019). NEL also correlated negatively and significantly with ADF and NDF, indicating that the higher the fiber contents, the lower the NEL (Espinoza-Canales, 2017). The variable TDN correlated positively and significantly ($p< 0.01$) with EE, CF and CP. These relationships, in these magnitudes and sense, represent the amount of digestible energy in the feed from the truly digestible fraction (Elizondo-Salazar, 2020). Negative and significant correlations ($p< 0.01$) were observed between TDN with ADF and NDF. It is known that TDN tends to decrease as ADF and NDF increase through the maturation process of fodders (Espinoza-Canales, 2017), so the cut date of the fodder will be decisive to maintain a content and availability of nutrients.

## Conclusions

As in most of the variables, except one, there was no significant difference between the two types of fertilization and since inorganic fertilization is more expensive than organic fertilization and in addition to the fact that organic products have greater acceptance in the market, it can be considered that organic fertilization is an additional option to inorganic fertilization to maintain the quality of the fodder. The combination between corn and Yorimón bean showed that it is an alternative to the conventional fodders used, in addition to the organic and sustainable nature that takes care of the environment because it does not pollute it and is available to the whole society.

## Cited literature


Agbogidi, O. M. 2010. Screening six ciltivars of cowpea *(Vigna unguiculata* (L.) Walp) for adaptation to soil contaminated with spent engine oil. J. Environ. Chem. Ecotoxicol. 7(2):103-109.

Agroder, S. C. 2012. Producción de maíz México. Comparativo estatal modalidad de temporal y riego. http://www.agroder.com/documentos/publicaciones/produccion_de-maiz_en_mexico AgroDer_2012.pdf.

Ahlgren, G. H. 1949. Forage crops. 1st Ed. McGraw-Hill. New York, USA. 418 p.

Anrique, G. R. 2014. Composición de alimentos para el ganado bovino. 4ta. Ed. América impresores. Chile, Chile. 91 p.

Apáez, B. P.; Escalante, E. J. A.; Rodríguez, G. M. T.; Olalde, G. V. M. y Ramírez, V. P. 2009. Frijol chino (*Vigna unguiculata* L. (Walp)) su cultivo, importancia económica y medicinal. Rev. Altern. 19(1):21-26.

Arnold, A. M.; Cassida, K. A.; Albrecht, K. A.; Hall, M. H.; Min, D.; Xu, X.; Orloff, S.; Undersander, D. J.; Van, S. E. and Sulc, R. M. 2019. Multistate evaluation of reduced-lignin alfalfa harvested at different intervals. Crop Sci. 4(59):1799-1807.

Ávila, M. M. R.; González, R. H.; Rosales, S. R; Espinoza, A. J. J.; Pajarito, R. A.; Zandate, H. R. y Herrera, M. D. 2010. Adoption and economic impact of Pinto Saltillo improved bean cultivar in North-Central México. Annual report of the bean improvement cooperative. 1(53):242-243.

Beltrán, M. F. A.; García, H. J. L.; Ruiz, E. F. H.; Fenech, L. L., Murillo, A. B.; Palacios, E. A. and Troyo, D. E. 2009. Nutrimental potential of red dolichos, brown dolichos and cowpea for green manure produced under three tillage Systems. Tropical and Subtrop. Agroecosyst. 3(10):487-495.

Blanco, C. F.; Loza, M. M. G.; Achu, N. C. y Chura, L. F. 2018. Producción de leche en vacas mestizo Holstein (*Bos taurus* L.) pastoreadas en paraderas nativas en comparación con las suplementadas con borra de cerveza y maíz amarillo. J. Selva Andina Animal Sci. 2(5):65-78.

Brautigan, I. M. 2007. Nutrición animal. 1ra. Ed. Universidad Estatal a Distancia. San José, Costa Rica. 120 p.

Campos-Granados C. M. y Arce-Vega, J. 2016. Sustitutos de maíz utilizados en la alimentación animal en costa rica. Nutrición Animal Tropical. 2(10):91-113.

Cañas, C. R. 1995. Alimentación y nutrición animal. Pontificia Universidad Católica de Chile, Facultad de Agronomía. Colección en Agricultura. Santiago, Chile. 50-575 pp.

Cardona, A. C.; Jarma, O. A. y Araméndiz, T. H. 2013. Mecanismos de adaptación a sequía en caupí (*Vigna unguiculata* L. Walp.). Una revisión. Rev. Colomb. Cienc. Hortíc. 7(2):277-288.

Carr, P. M.; Horsley, R. D. and Poland, W. W. 2004. Barley, oat and cereal-pea mixtures as dryland forages in the northern plains. Agron. J. 3(96):677-684.

Castro, M.; Díaz, J.; Castañeda, J.; Báez, L.; Hernández, L. L.; y Cabrera, J. J. and Cino, D. M. 2002. A nutritional alternative as protein source for growing pigs: *Vigna unguiculata* cv INIFAT-93. Cuban J. Agric. Sci. 4(36):347-350.

Clark, P. W.; Kelm, S. and Endres, M. I. 2002. Effect of feeding a corn hybrid selected for leafiness as silage or grain to lactating dairy cattle. J. Dairy Sci. 3(85):607-612.

Cook, B. G.; Pengelly, B. C.; Brown, S. D.; Donnelly, J. L; Eagles, D. A.; Franco, M. A.; Hanson, J. Mullen, B. F.; Partridge, I. J. and Peters, M. and Schultze, K. R. 2005. Tropical Forages: an interactive selection tool. Brisbane, Australia. https://hdl.handle.net/10568/33575.

Elizondo, S. J. A. 2020. Estimación de la energía calórica en alimentos para ganado de leche según el modelo del NRC (2001). Nutrición Animal Tropical. 14(2):39-50. Doi:10.15517/nat.v14i2.43614.

Espinoza, C. A.; Gutiérrez, B. H.; Sánchez, G. R. A.; Muro, R. A.; Gutiérrez, P. F. J. y Corral, L. A. 2017. Calidad de forraje de canola (*Brassica napus* L.) en floraciones temprana y tardía bajo condiciones de temporal en Zacatecas, México. Rev. Mex. Cienc. Pec. 8(3):243-248.

FAO. 2017. Organización de las Naciones Unidas para la Agricultura y la Alimentación. El trabajo de la FAO sobre el cambio climático. Conferencia de las Naciones Unidas sobre el cambio climático. Roma: Italia. 40 p. http://www.fao.org/3/a-i8037s.pdf. 2017.

Gallegos, P. A.; Martínez, R. A.; Fernando, S. M.; Figueroa, V. R.; Berumen, P. S.; Venegas, S. J.; Quevedo, G. J. D.; Escobedo, L. D. y Silos, C. M. C. 2012. Nutritional quality of forage maize (*Zea mays* L.) under limited water logging conditions. AGROFAZ. 12(1):59-66.

García, A. E. 1973. Modificaciones al sistema de clasificación climática de Köppen. Instituto de Geografía-Universidad Nacional Autónoma de México (UNAM). México, DF. 13-16 pp.

Gómez, P. E. J.; Argentel, M. L.; Ávila, A. C.; Alarcón, B. K.; López, S. R.; Ruiz, D. B.; Fernández, P. M. y Eichler, L. B. 2013. Evaluación de la tolerancia a la salinidad en frijol Caupí a partir de variables relacionadas con la nodulación y la acumulación de nitrógeno foliar. Cultivos Tropicales. 3(34):11-16.

Hoffman, P. C. 2005. Ash content of forages. Focus on forage. 1(7):1-2.

Inchausti, D. and Tagle, E. C. 1987. Bovinotecnia. 1ra. Ed. El Ateneo. Buenos Aires, Argentina. 729 p.

INIFAP. 2006. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Maíz forrajero de alto rendimiento y calidad nutricional. 1ra. Ed. Libro científico núm. 3.

Jayanegara, A.; Ridla, M.; Laconi, N.; Laconi, E. B. 2019. Estimation and validation of total digestible nutrient values of forage and concentrate feedstuffs. IOP Conf. Series: materials science and engineering. 546042016. 1- 5 pp. doi:10.1088/1757-899X/546/4/042016.

LACTODATA. 2011. Información sobre el sector lechero en México. 10-12 pp. http://www.lechemexico.org.mx.

Lewis, G.; Schrire, B.; Mackinder, B. and Lock, M. 2005. Legumes of the world. Royal Botanic Gardens, Kew. University of Chicago Press. Illinois, USA. 592 p.

López, G. C. M. y Bressani, R. 2008. Uso del cowpea (*Vigna unguiculata*) en mezclas con fríjol común (*Phaseolus vulgaris*) en el desarrollo de nuevos productos alimenticios. Archiv. Latinoam. Nutric. 1(58):71-80.

Mayz, J.; Larez, A. y Alcorces, A. 2010. Efectividad de cepas rizobianas nativas de sabana en *Vigna unguiculata* (L.) Walp. *cv* C4A-3. Rev. Colomb. Biotecnol. 2(12):194-202.

Moreno, G. J. 1982. El maíz forrajero: una opción en las explotaciones ganaderas. Pastos. 1(12):157 170.

Moreno-Resendes, A.; Cantú, B. J. E.; Reyes-Carrillo, J. L. and Contreras-Villareal, V. 2017. Forage maize nutritional quality according to organic and inorganic fertilization. Sci. Agropec. 1(8):127-135.

Murillo, A. B.; Troyo, D. E.; García, H. J. L.; Landa, H. L. y Larrinaga, M. J. A. 2000. El frijol Yorimón leguminosa tolerante a sequía y salinidad. 1ra. Ed. Centro de Investigaciones Biológicas del Noroeste. Baja California Sur, México. 5-6 pp.

NRC. 2001. National Research Council. Nutrients requirements of dairy cattle. 7th Ed. National Academy Press. Washington, DC, USA. 13-25 pp.

Phansak, P. P.; Taylor, P. W. J. and Mongkolporn, O. 2005. Genetic diversity in yard long bean (*Vigna unguiculata* ssp. sesquipedalis) and related Vigna species using sequence tagged microsatellite site analysis. Sci. Hortic. 2(106):137-146.

Ramakrishnan, K.; Gnanam, R.; Sivakumar, P. and Manickam, A. 2005. *In vitro* somatic embryogenesis from cell suspension cultures of cowpea (*Vigna unguiculata* (L.) Walp). Plant Cell Reports. 8(24):449-461.

Saha, U. K.; Sonon, L. S.; Hancock, D. W.; Hill, N. S.; Stewart, L.; Heusner, G. L. and Kissel, D. E. 2017. Common terms used in animal feeding and nutrition. Bulletin 1367. extension.uga.edu.

Sarmiento, F. L.; Gorocica, P. E.; Ramírez, A. L.; Castillo, C. J.; Santos, R. R. and Díaz, M. F. 2011. True metabolizable energy and digestibility of five *Vigna unguiculata* varieties in chickens. Trop. Subtrop. Agroecosyst. 14:179-183.

Serna, G. H. 2006. Servicio al cliente. Una nueva visión: clientes para siempre. 3ra. Ed. Bogotá, Colombia. 37-39 pp.

Sha, D.; Ming, X. and Junhu, Y. 2016. Relationship between fiber degradation kinetics and chemical composition of forages and by-products in ruminants. J. Appl. Animal Res. 1(44):189-193.

Shindoi, M. M. J. F.; Prause, J. and Jover, P. L. 2012. Descomposición de *Vigna unguiculata* (Caupí) en un Argiudol típico de colonia Benítez, Chaco. Rev. Inv. Agropec. 1(38):86-90.

SIAP. 2017a. Servicio de Información Agroalimentaria y Pesquera. Servicio de Información Agroalimentaria y Pesquera. http://infosiap.siap.gob.mx/repoAvance-siap-gb/pecAvanceProd.jsp.

SIAP. 2017b. Servicio de Información Agroalimentaria y Pesquera. Servicio de Información Agroalimentaria y Pesquera. Avance de siembras y cosechas.

Silva, T. M.; Medeiros, A. N.; Oliveira, R. L.; Gonzaga, N. S.; Queiroga, R. C.; Ribeiro, R. D.; Leão, A. G. and Bezerra, L. R. 2016. Carcass traits and meat quality of crossbred boer goats fed peanut cake as a substitute for soybean meal. J. Animal Sci. 7(94):2992-3000.

Singh, B. B.; Ajeigbe, H. A.; Tarawali, S. A.; Fernandez, R. S. and Abubakar, M. 2003. Improving the production and utilization of cowpea as food and fodder. Field Crops Res. 1-2(84):169-177.

Strydhorts, S. M.; King, J. R.; Lopetinsky, K. J. and Harker, K. N. 2008. Forage potential of intercropping barley with faba bean, lupin, or feal pea. Agron. J. 1(100):182-190.

Vargas, A. Y. R.; Villamil, O. E. L.; Murillo, P. O.; Murillo, A. W. y Solanilla, D. J. F. 2012. Caracterización fisicoquímica y nutricional de la harina de frijol caupí (*Vigna unguiculata)* L. cultivado en Colombia. Vitae. 1(19):320-321.

Vendramini, J. M. B.; Arthington, J. D. and Adesogan, A. T. 2012. Effects of incorporating cowpea in a subtropical grass pasture on forage production and quality and the performance of cows and calves. Grass Forage Science. 1(67):129-135.