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Leucaena leucocephala feeding systems for cattle production in Mexico

Sistemas de alimentación con Leucaena leucocephala *para la producción bovina en México*

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Abstract

The impacts of leucaena (*Leucaena leucocephala*) feeding systems on cattle production, environmental services and animal welfare in Mexico are discussed. A total of about 12,000 ha of leucaena have been established in the tropical regions of México, where most of the information for the current review was obtained. Incorporating leucaena in a grass pasture increases dry matter intake of grazing cattle and reduces the level of methane produced. This results in improved liveweight gains and milk yields as well as a reduction in the level of greenhouse gas released. Additional benefits are increases in soil carbon and nitrogen levels and less stress on animals as the leucaena plants provide shade and reduce environmental temperatures. While these benefits are substantial, the area developed to leucaena represents less than 0.1% of the area which could potentially be developed. Strategies to increase adoption of these grass-legume systems by farmers need to be developed to make effective use of the systems for increasing beef and milk production while reducing the undesirable environmental outcomes normally associated with ruminant production.

Keywords: Environmental services, liveweight gain, mitigation of methane emissions, tree legumes.

Resumen

Se discuten los impactos de los sistemas de alimentación con leucaena (*Leucaena leucocephala*) sobre la producción bovina, los servicios ambientales y el bienestar animal en México. En las regiones tropicales de México se han establecido cerca de 12,000 ha de leucaena, de donde se obtuvo la mayor parte de la información para la presente revisión. La incorporación de leucaena en las pasturas de gramíneas incrementa el consumo de materia seca de bovinos en pastoreo y reduce el nivel de metano producido. Esto resulta en incrementos en la ganancia de peso y rendimientos de leche, así como reducción del nivel de gas de efecto invernadero emitido. Beneficios adicionales de este sistema son los incrementos en los niveles de carbono y nitrógeno almacenados en el suelo y la reducción del estrés animal asociada con la sombra y la mitigación de las temperaturas ambientales aportada por la leucaena. A pesar de estos beneficios substanciales, el área establecida con leucaena representa únicamente el 0.1% del área potencial total que podría desarrollarse. Se requiere diseñar estrategias para incrementar la adopción de estos sistemas de gramíneas-leguminosas por los ganaderos para hacer un uso efectivo de los sistemas para incrementar la producción de carne y leche al mismo tiempo que se reducen los efectos indeseables en el ambiente usualmente asociados con la producción de rumiantes.

Palabras clave: Ganancia de peso vivo, leguminosas arbóreas, mitigación de emisiones de metano, servicios ambientales.

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Introduction

In Mexico, animal production systems which utilize leucaena (*Leucaena leucocephala*) can increase productivity, improve animal welfare and mitigate environmental impacts relative to grass-only systems (Figure 1), but adoption of these systems by commercial farmers is limited. In this review, we discuss the Mexican experience in terms of animal productivity, energy supplementation and environmental services. This analysis provides an understanding of the achievements that have been made and challenges facing the system.

Figure 1. Gyroland cattle in a leucaena-grass system for milk production.

Leucaena-grass systems can provide a wide range of ecosystem services. These include: reduction of greenhouse gas emissions through both mitigation of methane (CH_4) emissions and increased carbon (C) storage; improved nutrient cycling; increased soil organic matter; and improved atmospheric nitrogen (N) fixation.

Considerable effort has been made in various countries to improve our understanding of mechanisms of enteric CH_4 mitigation in cattle fed rations containing foliage of leucaena, notably in Australia (Harrison et al. 2015) and Colombia (Molina-Botero et al. 2016). In Mexico, respiration chamber methodology (Canul-Solis et al. 2017) has been used to measure enteric CH_4 emissions in cattle fed leucaena.

In the tropical regions of Mexico, environmental temperatures and relative humidity are high, and at certain times of the day (during summer), above the physiological capacity of livestock to dissipate body heat. This condition leads to low animal productivity due to elevated body temperature and respiratory rate, leading to reduced voluntary feed intake. A strategy to improve animal comfort is the inclusion of woody species in monocrop-grass systems (Figure 2).

Figure 2. Leucaena-grass-trees systems have the potential to improve animal comfort.

Materials and Methods

Information analyzed in the current review was generated from several regions of the Mexican tropics, particularly the states of Michoacán and Yucatán. In those regions, leucaena has been established by 615 livestock owners (mainly cattle producers) located in 10 different states (Campeche, Chiapas, Guerrero, Jalisco, Michoacán, Quintana Roo, San Luis Potosí, Tamaulipas, Veracruz and Yucatán), with a total livestock production area of 27,307,096 ha (Sagarpa 2014) of which about 14,906,331 ha are appropriate for leucaena establishment. This indicates the enormous potential to expand the planting of this legume, since only about 0.08% (12,000 ha) has been successfully established to date.

Animal performance and energy supplementation trials have been carried out using crossbred (*Bos taurus* × *B. indicus*) cattle. Levels of C storage, N fixation and nutrient cycling were quantified in commercial grass-only pastures and leucaena-grass associations under grazing.

Environmental services of leucaena feeding systems

Methane mitigation in crossbred cattle fed rations containing leucaena

Trials carried out in open-circuit respiration chambers revealed that, as the level of chopped fresh foliage of leucaena was increased in a basal ration of a low-quality grass (*Cenchrus purpureus* syn. *Pennisetum purpureum*), enteric CH_4 emissions of cattle decreased linearly (Piñeiro-Vázquez et al. 2018) (Table 1). This confirmed previous results by Harrison et al. (2015) in Australia. It is possible that condensed tannins contained in leucaena foliage induced changes in the microbial population of the rumen, thus affecting methanogenic *Archaea* and decreasing CH_4 emissions. Energy loss through CH_4

Table 1. Effects of increasing levels of incorporation of leucaena forage in a basal ration of low-quality *Cenchrus purpureus* (syn. *Pennisetum purpureum*) grass for cattle on emissions of enteric methane and dry matter digestibility (Piñeiro-Vázquez et al. 2018).

Parameter	Leucaena level in the ration (% DM)					s.e.	Linear
	0	20	40	60	80		
Cattle LW (kg)	293	298	289	298	295	6.8	
Intake (kg DM/hd/d)	7.0	7.2	7.1	7.0	7.0	0.6	NS
Methane (L/hd/d)	137.3	101.2	87.4	74.9	53.5	14.8	**
Methane (L/kg DMI)	20.1	14.7	12.1	10.5	7.7	2.1	**
Digestibility (% DM)	54.2	50.5	47.8	46.9	46.6	4.0	NS

LW = live weight; DMI = Dry matter intake.

production, as percentage of gross energy intake (Y_m), fell from 5.2% for the grass-only ration, to 3.6%, when leucaena was fed at 20% of ration dry matter (DM), and it continued to fall as legume levels were increased. DM digestibility also decreased as leucaena percentage in the ration increased, but differences were not significant. These findings suggest that incorporating leucaena at 20% of ration DM would reduce CH_4 emissions by around 25%, relative to a grass-only diet. This represents an important outcome from both an environmental point of view (reduction of CH_4 production and emission) and animal performance (improvement through reduced energy loss).

Carbon storage and N cycling increased

Carbon storage and N cycling increased by 38 and 47%, respectively, in leucaena-grass systems compared with pure grass pastures. The legume fixed more than 200 kg N/ha/yr and soil organic matter increased by about 200% in the legume association compared with the grass-only system. Environmental temperature was reduced by almost 13% in the legume tree-grass system (Table 2).

Table 2. Environmental factors in leucaena-grass and grass-only systems recorded in Michoacán, Mexico (Solorio Sánchez et al. 2009; Sarabia 2013; López-Santiago et al. 2019).

Environmental factor	Grass only	Leucaena-grass
Total C storage (t/ha/yr)[1]	78	120
Temperature (°C)[2]	34–38	30–34
Nutrient recycling (kg/ha/yr)	1–15 (N), 6 (P), 17 (K)	22–30 (N), 4 (P), 2 (K)
Soil organic matter (kg/ha)[3]	320	1,005
Atmospheric N fixation (kg/ha/yr)	0	200–300

[1]Above- and below-ground (0–0.30 m soil depth) carbon.
[2]Measured at 0.80 m above ground in the grass-monocrop and in the tree shade in the leucaena-grass system. Range recorded during April-May (dry season) and June (early rainy season) at 12:00 h.
[3]Measured from 0 to 0.60 m soil depth.

Animal performance

Intake and productivity of animals grazing leucaena

Farmers are interested in knowing the amount of leucaena forage consumed under practical grazing conditions in a leucaena-grass system to achieve maximum benefit. In south-east Mexico, Bottini-Luzardo et al. (2016) measured the intakes of both grass and leucaena under grazing conditions (n-alkane technique) and observed that dual-purpose lactating cows were able to browse 34% of their diet as leucaena. That level of leucaena DM intake will probably correspond with a reduction in CH_4 emissions of around 30%, which is a substantial decrease on environmental grounds. Piñeiro-Vázquez et al. (2018) demonstrated in a respiration chamber experiment with heifers that feeding 20% (of ration DM) leucaena (in a basal ration of tropical grass) induced a reduction of 26% in CH_4 emission while 40% leucaena gave a reduction of 36%. It is reasonable to assume that 34% of ration DM (Bottini-Luzardo et al. 2016) would probably lead to a reduction of around 30% in CH_4 emissions. This guesstimate agrees, in general, with results obtained at other laboratories. Intakes of leucaena reported by Bottini-Luzardo et al. (2016) agreed with results reported by Sierra-Montoya et al. (2017), who found a leucaena intake (DM) of around 28% of the diet in dual-purpose lactating cows grazing in a silvopastoral system in Colombia. Steers in silvopastoral systems with leucaena (without supplementation) gained 770 g/hd/d (Mayo-Eusebio et al. 2013), with associated benefits of improvement in carcass yield and lean meat production, made possible through desired fatty acid composition and high concentration of unsaturated fatty acids (Rodríguez-Echevarria et al. 2013).

Energy supplementation to increase efficiency of nitrogen (N) utilization

Intake of crude protein (CP) by cattle grazing in paddocks with high leucaena plant densities (about 35,000 plants/ha), as currently used in Mexico, could be high, resulting in excessive losses of N in the urine (Bottini-Luzardo et al. 2015). This may increase energy requirements for maintenance of cattle (Jennings et al. 2018) and increase N_2O emissions from the urine (Bao et al. 2018). There may also be an imbalance in the protein:energy ratio in the rumen leading to inefficient microbial protein synthesis (Calsamiglia et al. 2010; Barros-Rodríguez et al. 2013). Blood urea nitrogen (BUN) is a good indicator of nutritional balance in ruminants and the protein:energy ratio in total dietary intake is the most important factor related to fluctuations in BUN (Hess et al. 1999). In south-east Mexico, Ruiz-González (2013) found that both BUN and urinary N excretion in cows increased linearly with increasing levels of leucaena in the diet, suggesting inefficient use of N in the rumen. In addition, Arjona (2015) compared cane molasses, sorghum grain, citrus peel and rice polishing as energy supplements for lactating Holstein × Zebu cows fed a diet containing 45% leucaena foliage, relative to a control treatment without energy supplementation. Both BUN and urinary excretion of N were higher for the control group than for the supplemented treatments, suggesting that energy supplementation improved the utilization of N in the rumen. Total feed intake was 25% higher and milk yield was increased by 30% with energy supplementation, with no differences due to the particular energy sources. It was concluded that energy supplementation, regardless of the source used, will improve the efficiency of microbial protein synthesis in the rumen, as well as increase consumption of DM and animal performance, in cattle fed rations incorporating leucaena (Castillo et al. 2000).

Animal welfare

In the central part of Mexico, growing bullocks grazing leucaena associated with *Megathyrsus maximus* had lower body temperature (measured with an infrared thermometer) and respiratory rates in the morning (36 vs. 38 °C and 42 vs. 65 breaths per minute) and in the afternoon (38 vs. 39.5 °C and 59 vs. 80 breaths per minute) than in a feedlot (Utrilla-García 2013). This suggests that the feedlot system, which is becoming a common practice in Mexico, can have negative impacts on animal welfare and productivity, if shade is not provided, since it could reduce feed intake and liveweight gain and therefore general productivity. In another study, undertaken in southeast Mexico, to evaluate animal welfare of dairy cattle grazing leucaena-grass systems with trees, improved microclimate conditions allowed animals to cope better with heat stress. In addition to increased biodiversity there were advantages for animal welfare in terms of social and affiliative behavior, such as social licking, head leaning and social rubbing (Améndola et al. 2015).

Leucaena-grass system adoption

From 2012 to 2017, leucaena-grass systems have been established over almost 12,000 ha (615 farms), which represents about 0.08% of the total livestock area suitable for leucaena establishment (14,906,331 ha) in 10 states of the tropical region in Mexico. Although this area is significant, the rate of adoption has been slow and limited, as there are more than 350,000 cattle farms in the tropical region (PGN 2018). Possible contributing factors are: a) uncertainty in livestock markets; b) lack of state laws that give long-term support to this initiative; c) lack of long-term extension services for cattle producers; d) high labor demand for leucaena-based systems, which means farmer leaders must have confidence in the system; e) lack of availability of good quality farm inputs and services and the need for an appropriate market-chain for distribution; f) inefficient support from state policies; and g) high costs and limited access to credit.

Conclusions

Leucaena feeding systems could be an important strategy in the tropical regions of Mexico to improve animal productivity and welfare, and to reduce greenhouse gas emissions to the environment.

Silvopastoral systems with leucaena have proved highly productive in Mexico. However, these systems have not been adopted widely by farmers, mainly due to lack of readily available technical support, several socio-economic and political constraints and appropriate strategies to make effective use of the systems for cattle production with minimal impact on the environment.

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References

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Améndola L; Solorio FJ; Ku-Vera JC; Améndola-Massiotti RD; Zarza H; Galindo F. 2015. Social behaviour of cattle in tropical silvopastoral and monoculture systems. Animal 10:863–867. doi: 10.1017/S1751731115002475

Arjona AV. 2015. Evaluación de cuatro suplementos energéticos sobre el comportamiento productivo en vacas de doble propósito alimentadas con follaje de *Leucaena leucocephala* y *Pennisetum purpureum*. M.Sc. Thesis. Universidad Autónoma de Yucatán, Mérida, Yucatán, Mexico.

Bao Y; Zhou K; Zhao G. 2018. Nitrous oxide emissions from the urine of beef cattle as regulated by dietary crude protein and gallic acid. Journal of Animal Science 96:3699–3711. doi: 10.1093/jas/sky252

Barros-Rodríguez M; Solorio-Sánchez J; Sandoval-Castro C; Klieve AV; Briceño-Poot E; Ramírez-Avilés L; Rojas-Herrera R. 2013. Effects of two intake levels of *Leucaena leucocephala* on rumen function of sheep. Tropical Grasslands-Forrajes Tropicales 1:55–57. doi: 10.17138/TGFT(1)55-57

Bottini-Luzardo M; Aguilar-Pérez C; Centurión-Castro F; Solorio-Sánchez FJ; Ayala-Burgos A; Montes-Pérez R; Muñoz-Rodriguez D; Ku-Vera J. 2015. Ovarian activity and estrus behavior in early postpartum cows grazing *Leucaena leucocephala* in the tropics. Tropical Animal Health and Production 47:1481–1486. doi: 10.1007/s11250-015-0887-3

Bottini-Luzardo MB; Aguilar-Pérez CF; Centurión-Castro FG; Solorio-Sánchez FJ; Ku-Vera JC. 2016. Milk yield and blood urea nitrogen in crossbred cows grazing *Leucaena leucocephala* in a silvopastoral system in the Mexican tropics. Tropical Grasslands-Forrajes Tropicales 4:159–167. doi: 10.17138/TGFT(4)159-167

Calsamiglia S; Ferret A; Reynolds CK; Kristensen NB; van Vuuren AM. 2010. Strategies for optimizing nitrogen use by ruminants. Animal 4:1184–1196. doi: 10.1017/S1751731110000911

Canul Solís JR; Piñeiro Vázquez AT; Arceo Castillo JI; Alayón Gamboa JA; Ayala Burgos AJ; Aguilar Pérez CF; Solorio Sánchez FJ; Castelán Ortega OA; Lachica López M; Quintana Owen P; Ku-Vera JC. 2017. Design and construction of low-cost respiration chambers for ruminal methane measurements in ruminants. Revista Mexicana de Ciencias Pecuarias 8:185–191. doi: 10.22319/rmcp.v8i2.4442

Castillo AR; Kebreab E; Beever DE; France J. 2000. A review of efficiency of nitrogen utilisation in lactating dairy cows and its relationship with environmental pollution. Journal of Animal and Feed Science 9:1–32. doi: 10.22358/jafs/68025/2000

Harrison MT; McSweeney C; Tomkins NW; Eckard RJ. 2015. Improving greenhouse gas emissions intensities of subtropical and tropical beef farming systems using *Leucaena leucocephala*. Agricultural Systems 136:138–146. doi: 10.1016/j.agsy.2015.03.003

Hess HD; Flórez H; González E; Ávila M. 1999. Efecto del nivel de nitrógeno amoniacal en el rumen sobre el consumo voluntario y la digestibilidad in situ de forrajes tropicales. Pasturas Tropicales 21(1):43–49. bit.ly/2ToM0B4

Jennings JS; Meyer BE; Guiroy PJ; Cole NA. 2018. Energy costs of feeding excess protein from corn-based by-products to finishing cattle. Journal of Animal Science 96:653–669. doi: 10.1093/jas/sky021

López-Santiago JG; Casanova-Lugo F; Villanueva-López G; Díaz-Echeverría VF; Solorio-Sánchez FJ; Martínez-Zurimendi P; Aryal DR; Chay-Canul AJ. 2019. Carbon storage in a silvopastoral system compared to that in a deciduous dry forest in Michoacán, Mexico. Agroforestry Systems 93:199–211. doi: 10.1007/s10457-018-0259-x

Mayo-Eusebio R; Utrilla-García MP; Aguilar-Pérez CF; Solorio-Sánchez FJ; Ayala-Burgos AJ; Briceño-Poot EG; Ramírez-Avilés L; Ku-Vera JC. 2013. Productive performance of growing cattle grazing a silvopastoral system with *Leucaena leucocephala*. In: Proceedings of the 22nd International Grassland Congress, Sydney, Australia, 15–19 September 2013. p. 1013–1014.

Molina-Botero IC; Angarita EA; Mayorga OL; Chará J; Barahona-Rosales R. 2016. Effect of *Leucaena leucocephala* on methane production of Lucerna heifers fed a diet based on *Cynodon plectostachyus*. Livestock Science 185:24–29. doi: 10.1016/j.livsci.2016.01.009

PGN (Padrón Ganadero Nacional). 2018. Estadística Pecuaria, PGN Bovinos. bit.ly/2Mfg9lM

Piñeiro-Vázquez AT; Canul-Solís JR; Jiménez-Ferrer GO; Alayón-Gamboa JA; Chay-Canul AJ; Ayala-Burgos AJ; Aguilar-Pérez CF; Ku-Vera JC. 2018. Effect of condensed tannins from *Leucaena leucocephala* on rumen fermentation, methane production and population of rumen protozoa in heifers fed low-quality forage. Asian Australasian Journal of Animal Sciences 31:1738–1746. doi: 10.5713/ajas.17.0192

Rodríguez Echevarria ME; Corral-Flores G; Solorio Sánchez B; Alarcón Rojo AD; Grado-Ahuir JA; Rodríguez-Muela C; Cortés Palacios L; Segovia Beltrán VE; Solorio Sánchez FJ. 2013. Meat quality from cattle fattened in intensive silvopastoril system in two seasons of the year. Tropical and Subtropical Agroecosystems 16:235–241. bit.ly/2GY1s23

Ruiz-González A. 2013. Balance de nitrógeno y composición de leche de vacas alimentadas con *Leucaena leucocephala*. M.Sc. Thesis. Universidad Autónoma de Yucatán, Mérida, Yucatán, Mexico.

Sarabia SL. 2013. Efecto de la frecuencia de poda en *Leucaena leucocephala* y *Panicum maximum* sobre la fijación y transferencia de nitrógeno atmosférico en Sistemas Silvopastoriles Intensivos. M.Sc. Thesis. Universidad Autónoma de Yucatán, Mérida, Yucatán, Mexico.

Sagarpa (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación). 2014. Comisión Técnico Consultiva de Índices de Agostadero (Cotecoca). bit.ly/2MXkXMi

Sierra-Montoya E; Chará JD; Barahona-Rosales R. 2017. The nutritional balance of early lactation dairy cows grazing intensive silvopastoral systems. Ciência Animal Brasileira, Goiânia 18:1–12. doi: 10.1590/1089-6891v18e-40419

Solorio Sánchez FJ; Bacab Pérez H; Castillo Caamal JB; Ramírez Avilés L; Casanova Lugo F. 2009. Potencial de los sistemas silvopastoriles en México. Proceedings of the II

Congreso en Sistemas Silvopastoriles, Morelia, Mexico, 3–5 November 2009. p. 21–30.

Utrilla-García MP. 2013. Conducta ingestiva e indicadores fisiológicos de toros en crecimiento en un sistema silvopastoril con *Leucaena leucocephala* asociado con *Panicum maximum*. M.Sc. Thesis. Universidad Autónoma de Yucatán, Mérida, Yucatán, Mexico.

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