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ARTÍCULO ORIGINAL

Bromatological and energy characterization of six tree species with forage potential in the dry tropic region in Sinaloa, Mexico

Caracterizaciones bromatológicas y energéticas de seis especies de árboles con potencial forrajero en la región tropical seca en Sinaloa, México

Caracterizações bromatológicas e energéticas de seis espécies de árvores com potencial forrageiro na região tropical seca de Sinaloa, México.

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Abstract

The objective of this research was to identify the tree species used in feeding cattle, as well as their density and nutritional value in Sinaloa, Mexico. The study was carried out through monthly samplings and a survey to producers. The variables evaluated were Dry Matter (DM), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Cellular Content (CC), Potential Dry Matter intake (PDMI), Digestible Energy (DE), Net Energy for maintenance (NE_m), Net Energy forgain ($NE_{g)}$, Net Energy for lactation (NE_l), Total Digestible Nutrients (TDN) and Growing Degree Days (GDD). The results showed the following order of tree consumption preference by cattle: (1) *Lysiloma divaricatum*, (2) *Acacia farnesiana*, (3) *Ebenopsis ebony*, (4) *Tabebuia rosea*, (5) *Guazuma ulmifolia* and (6) *Chloroleucon mangense* Jacq. The NDF content was the highest in *Tabebuia rosea* (54.4%) as well as in ADF (42.8%) and *Ebenopsis ebano* was the lowest (19.3%). The highest content was observed in *Ebenopsis ebano* (4.9%) and *Acacia farnesiana* (3.7%). The highest NE_l content was observed in *Tabebuia rosea* (1.99 Mcal/kg DM), and the lowest in *Guazuma ulmifolia* (1.26 Mcal/kg DM). *Ebenopsis ebano* showed, the highest content was observed in NE_l (1.86 Mcal/kg DM) and the lowest was observed in *Tabebuia rosea* (1.22 Mcal/kg DM). A significant difference ($P<0.05$) was observed in the accumulation of average GDD per day by forage species. *Acacia farnesiana* is the forage tree with the highest consumption by cattle and the one that presented the highest density in the sampled area. *Chloroleucon mangense* is the second most important species, despite its low density in the study area. GDD were higher in the summer season, while the lowest amount occurred in autumn, which was reflected in differences in the quality and quantity of the forage.

Keywords: agroforestry; ruminants; nutrition

Resumen
El objetivo fue identificar las especies arbóreas utilizadas en la alimentación del ganado, su densidad y valor nutricional en Sinaloa, México. Se realizó un muestreo mensual y una encuesta a productores. Las variables evaluadas fueron Materia Seca (DM), Fibra Detergente Neutra (NDF), Fibra Detergente Acida (ADF), Contenido Celular (CC), Consumo Potencial de Materia Seca (PDMI), Energía Digestible (DE), Energía Neta de Mantenimiento (NE_m), Energía Neta de Ganancia (NE_g), Energía Neta de Lactancia (NE_l), Nutrientes Totales Digeribles (TDN) y Grados Día de Crecimiento (GDD). Los resultados indicaron el siguiente orden de preferencia por el ganado: (1) *Lysiloma divaricatum*, (2) *Acacia farnesiana*, (3) *Ebenopsis ébano*, (4) *Tabebuia rosea*, (5) *Guazuma ulmifolia* y (6) *Cloroleucon mangense*. El contenido de NDF fue mayor en *Tabebuia rosea* (54.4%) y ADF (42.8%) y *Ebenopsis ebano* fue el menor (19.3%). El mayor contenido de ADF se observó en *Ebenopsis ebano* (4.9%) y *Acacia farnesiana* (3.7%). El mayor contenido de NE_l se observó en *Tabebuia rosea* (1.99 Mcal/kg MS), y el menor en *Guazuma ulmifolia* (1.26 Mcal/kg MS). En NE_l, en *Ebenopsis ebano* se observó el mayor contenido (1.86 Mcal/kg MS) y el menor se observó en *Tabebuia rosea* (1.22 Mcal/kg MS). Se observó una diferencia significativa (P<0.05) en la acumulación de GDD promedio por día por especie forrajera. *Acacia farnesiana* fué el de mayor consumo y el que presentó mayor densidad en el área muestreada. *Chloroleucon mangense* es la segunda especie en importancia, a pesar de su baja densidad en el área de estudio. Los GDD fueron mayores en la temporada de verano, mientras que la menor cantidad se presentó en otoño, lo que se reflejó en diferencias en la calidad y cantidad de los árboles forrajeros.

Palabras clave: agroforestería; rumiantes; nutrición

Resumo
O objetivo foi identificar as espécies arbóreas utilizadas na alimentação do gado, sua densidade e valor nutricional em Sinaloa, México. Foi realizada uma amostragem mensal e uma enquete voltada aos produtores. As variáveis avaliadas foram Matéria Seca (DM), Fibra em Detergente Neutro (NDF), Fibra em Detergente Ácido (ADF), Conteúdo Celular (CC), Consumo Potencial de Matéria Seca (PIMS), Energia Digestível (DE), Energia Líquida de Mantença (NE_m), Energia Líquida de Ganho (NE_g), Energia líquida de lactação (NE_l), Nutrientes Digestíveis Totais (TDN) e Graus Dias de Crescimento (DDG). Os resultados indicaram a seguinte ordem de preferência pelo gado: (1) *Lysiloma divaricatum*, (2) *Acacia farnesiana*, (3) *Ebenopsis ébano*, (4) *Tabebuia rosea*, (5) *Guazuma ulmifolia* e (6) *Chloroleucon mangense*. O conteúdo de NDF foi maior em *Tabebuia rosea* (54.4%) e ADF (42.8%) e *Ebenopsis ebano* foi o menor (19.3%). Os maiores teores de ADF foram observados em *Ebenopsis ebano* (4.9%) e *Acacia farnesiana* (3.7%). O maior teor de NE_l foi observado em *Tabebuia rosea* (1.99 Mcal/kg MS), e o menor em *Guazuma ulmifolia* (1.26 Mcal/kg MS). No NE_l, o maior teor foi observado em *Ebenopsis ebano* (1.86 Mcal/kg DM) e o menor em *Tabebuia rosea* (1.22 Mcal/kg MS). Foi observada uma diferença significativa (P<0.05) no acúmulo médio de DDG por dia por espécie forrageira. A *Acacia farnesiana* apresentou o maior consumo e a maior densidade na área amostrada. A *Chloroleucon mangense* é a segunda espécie mais importante, apesar de sua baixa densidade na área de estudo. Os DDG foram maiores no verão, enquanto a menor quantidade foi no outono, o que se refletiu nas diferenças na qualidade e quantidade das árvores forrageiras.

Palavras-chave: agrofloresta; ruminantes; nutrição

Introduction

Around 60% of the total livestock produced worldwide is found in the tropics (Botero and Russo, 1998). In the dry season, tropical grasses are characterized by low levels of crude protein and a high content of fiber with the consequent low digestibility and production in general (Botero and Russo, 1998; Ortega-Gómez *et al*., 2011). The importance and productivity of some tree species as a source of forage have recently been highlighted as an alternative to compensate for the forage deficit that occurs in tropical areas during the dry months (Wagner, 2013; Cabrera-Nuñez *et al*., 2019).
In these areas, trees not only contribute to improving soil fertility but also provide organic matter and nutrients (Ramírez-Builes, 2007). Trees allow nutrient recycling in deep soil layers which cannot be penetrated by the roots of herbaceous plants (Torres-Guerrero *et al*., 2013;

Crespo, 2015). Furthermore, trees provide food (Cabrera-Nuñez, 2019) and improve microclimatic conditions by providing shade (Lucero-Ignamarca *et al*., 2019; Meili *et al*., 2021) and keeping cattle body temperature within a comfortable range (Kamal *et al*., 2018; Edwards-Callaway *et al*., 2021). When cattle consume the fruits of trees, they not only take advantage of the nutrients but also contribute to seed scarification and dispersal (Tjelele *et al*., 2015; Treitler *et al*., 2017).

The potential of silvopastoral systems is high if we consider the existence of numerous tree species of great biological diversity which can function as fundamental components of such systems (Kaushal *et al*., 2017; Cabrera-Nuñez *et al*., 2019). Tree species in the Fabaceae family have the greatest potential for agrosilvopastoral systems (Rendón-Sandoval *et al*., 2020), and livestock producers supply mixtures of these fodder tree leaves to cattle either as a supplement or as the only feed (Beigh *et al*., 2017; Cabrera-Nuñez *et al*., 2019).

The use of mixtures ensures a more diverse supply of forages and, therefore, reduces the risk of dependence on a single plant species (Méndez, 1998; Lüscher *et al*., 2014). Producers use genetic diversity as a form of quality assurance, since in marginal environments, uniformity can lead to the total failure of a crop in difficult circumstances (Cooper, 1992; Govindaraj *et al*., 2015).

Nitis *et al*. (1990) described a multi-strata forage production system, which includes grasses and creeping legumes (first stratum), legumes and shrubs (second stratum), and fodder trees (third stratum). The multi-strata system (0.25 ha) produced more forage and supported higher stocking rates than a non-stratified system (0.5 ha), which was reflected in lower infestation of endoparasites, less erosion, higher organic matter and nitrogen content in the soil and, even after five years, a higher production of firewood and greater economic benefits.

Méndez (1998) concludes that the study of agroforestry systems is important for the tropics and that their practical application requires consideration in the context of sustainable agriculture. Therefore, the objective of this research was to identify the tree species used in cattle feeding, as well as their nutritional value, in a dry tropical area in the state of Sinaloa, Mexico.

Materials and methods

The study was carried out in the municipality of Culiacán, in the central part of the state of Sinaloa, at 107°24' W and 24°55' N, at an altitude of 88 m. The average annual temperature is 25.1 ºC. January is the coldest month (19.3 ºC) and July the hottest (30.3 ºC). The climate is defined as BS1(h') w(e) warm and semi-dry extreme, with an annual precipitation of 724.4 mm, the maximum occurring in August (24.1 mm) and the minimum in May (1.6 mm) (García, 1987).

A survey was carried out to identify the main tree species consumed by cattle and their uses other than as a forage, using a questionnaire that collected the following information: name of the respondent, location, occupation, known forage species, if cattle consume them, and the most common species in the region. The survey was administered directly to 150 livestock producers in seven locations in the municipality of Culiacán (Jesús María, Las Higueras, La Anona, El Varejonal, Los Limones, El Limoncito and Las Guásimas). The sample size was determined according to Odalys *et al*. (2008). Six forage trees were evaluated from May to November 2016, following the methodology of Scheaffer *et al.* (1987). A stratified random sampling (SRS) was carried out in the field to identify the representative units of each species, which were subsequently classified taxonomically. Using an ordinal scale, we ordered hierarchically the previously identified forage trees according to intake by cattle in the study area. Similarly, the abundance of each species was determined on the basis of tree density.

The research focused on six species: mauto (*Lysiloma divaricatu*m (Jacq.) JF Macbr.), vinolo (*Acacia farnesiana* L. Wild), ebony (*Ebenopsis ebano* Berl.), amapa (*Tabebuia chrysantha* Jacq.), guasima (*Guazuma ulmifolia* Lam.) and palo pinto (*Chloroleucon mangense* Jacq.). Forage species were sampled monthly using the forage sampling technique described by Shinozaki *et al*. (1964). The optimal sample size was estimated for each species (Scheaffer *et al*., 1987) to assess production on a dry basis. Seven samples of vegetative material consisting of leaves, pods and fruits were collected by the end of each month. The samples were weighed at the time of collection, labeled and placed in paper bags to be dried in an oven at 65 °C for 48 h. Dried samples were processed in a Willey #4 mill using a 1-mm mesh sieve, and stored in hermetically sealed glass containers for subsequent analysis.
The samples of each forage tree were subjected to the following analyses: Apparent Dry Matter (ADM, dried at 60°C for 48 h), Residual Dry Matter (RDM, dried at 105°C for 24 h), crude protein (CP) by the Kjelhdal method, ashes (AOAC, 1999), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) (Goering and Van Soest, 1970), Cellular Content (CC), and Organic Matter (OM).
The analyses were performed in the Bromatology and Animal Nutrition Laboratory of the College of Agronomy of the Universidad Autónoma de Sinaloa. The variables of interest were: green forage production (kg/ha^{-1}) and forage production based on dry matter (kg DM/ ha^{-1}), bromatological composition, leaf area, potential consumption and Growing Degree Days (GDD).
The energy (Mcal/kg^{-1} of DM), the net energy for gain (NE_g), net energy for lactation (NE_l), and percentage of total digestible nutrients (% TDN) of the forage trees analyzed were characterized. NE_l is defined as the energy contained in forages to produce milk. Broadly, 70 to 80% of energy is used for metabolism, and 40% to 60% for reproductive processes and milk production (Shirley, 1986).
The potential dry-matter intake and protein (PDMI) was estimated as a percentage of the live weight of the ruminant for each forage species, estimated from the NDF content of the forage. GDDs were obtained as indicated by Frank (1996), setting the minimum and maximum thresholds at 10 and 35 ºC (Salisbury *et al.*, 1994) and subtracting the Celsius degrees exceeding the maximum threshold from the GDD of the day. Temperature records were obtained from the National Weather Service. The model for determining GDD was as follows:

$$\left[\left(\frac{Tmax + Tmin}{2}\right) - Tbase\right] - °C > UM$$

Where:
GDD = Growing Degree Day
Tmax = Maximum daily temperature
Tmin = Daily minimum temperature
Tbase = physiological initial temperature
°C > UM = Centigrade degrees above the Physiological Maximum Threshold.

The physiological initial temperature (Tbase) was established at 10 °C (Guerra and Calderón, 1997), and the maximum physiological threshold at 35 °C (Guerra *et al.*, 1999). A randomized complete block design (RCDB, with each block corresponding to each sampling site for each species evaluated) was used for the response variables: DM, NDF, ADF, CC, PDMI, DE, NE_m, NE_g, NE_l, TDN and monthly GDD (Barreras *et al.*, 1999). Data were analyzed with ANOVA

(SAS, 2009) and treatment (species) means were compared with the Tukey test considering an error rate of 5%. The design used was represented by the following statistical model:

$$y_{ij} = \mu + T_i + B_j + E_{ij}$$

Where:
Yij = Dependent variable
µ = Population means
Ti = Effect of the i-th treatment (tree species)
Bj = Effect of the j-th block (sampling site)
Eij = Random error
Assumptions: Errors are ~ N I (0, ó²).

Results

The results of the survey indicated the following order of importance for the forage trees most consumed by livestock in the study area: 1) *Lysiloma divaricatu*, 2) *Acacia farnesiana*, 3) *Ebenopsis ebano*, 4) *Tabebuia chrysantha*, 5) *Guazuma ulmifolia*, and 6) *Chloroleucon mangense*.
It was also found that local people also use the forage tree species as firewood, wood, for making poles, and as traditional medicines (Table 1).

Table 1. Forage tree species in the dry tropics of Sinaloa, Mexico.

Common name	Scientific name	Use	Preference in consumption by livestock	Order in density
Vinolo	*Acacia farnesiana*	Firewood	1	1
Amapa	*Tabebuia rosea*	Wood	6	4
Mauto	*Lysiloma divaricatum*	Poles	5	2
Palo pinto	*Chloroleucon mangense*	Wood	2	5
Guásima	*Guazuma ulmifolia*	Medicinal	3	3
Ébano	*Ebenopsis ebano*	Wood	4	6

Note: Samples consisted of leaves and tender fruits for all species except for guásima, which consisted of leaves and ripe fruit.

The results of the bromatological analyses are shown in Table 2. *Tabebuia rosea* had the highest NDF average percentage (x̄=54.42), and the lowest percentage (x̄=25.79) was in *Ebenopsis ebony*. The highest ADF percentage (x̄=42.83) was found in *Tabebuia rosea*, followed by *Guazuma ulmifolia* (x̄=33.54). The lowest percentages occurred in *Acacia farnesiana* and *Ebenopsis ebano*, with x̄=24.79 and x̄=19.33, respectively.
The highest percentage of PDMI (x̄=4.89) was found in *Ebenopsis ebano*, and the lowest (x̄=2.4) in *Tabebuia rosea*.

Table 2. Bromatological characterization of six tree forage species in the dry tropics of Sinaloa, Mexico.

Species	DE	NE_m	NE_g	NE_l	TDN
Ebenopsis ebano	3.55[a]	2.34[a]	1.93[a]	1.86[a]	80.81[a]
Acacia farnesiana	3.29[ab]	2.11[b]	1.65[b]	1.71[ab]	74.72[ab]
Tabebuia rosea	2.40[d]	2.56[a]	1.99[a]	1.22[d]	54.64[d]
Lysiloma divaricatum	2.98[bc]	1.91[c]	1.42[c]	1.54[bc]	67.78[bc]
Guazuma ulmifolia	2.86[c]	1.77[d]	1.26[d]	1.47[c]	64.98[c]
Chloroleucon mangense	3.09[bc]	2.00[c]	1.53[c]	1.60[bc]	70.38[bc]
CV (%)	8.63	4.03	6.33	9.28	8.63

Means followed by a different superscript letter differ significantly (P<0.05).
DM (%): Dry Matter; NDF (%): Neutral Detergent Fiber; ADF (%): Acid Detergent Fiber; CC: Cellular Content; PDMI: Potential Dry Matter Intake as a percentage of live weight. CV: Coefficient of variation.

Regarding the energy characterization of the species studied, NE_g (defined as the energy of the forages used for growth or weight gain) was highest in *Tabebuia rosea* and *Ebenopsis ebano* ($\bar{x}$=1.99 and $\bar{x}$=1.93 Mcal/kg^{-1}, respectively), and lowest in *Guazuma ulmifolia* ($\bar{x}$=1.26 Mcal/kg^{-1}). NE_g The highest NE_l content was found in *Ebenopsis ebano* ($\bar{x}$=1.86 Mcal/kg^{-1}), and the lowest in *Tabebuia rosea* with $\bar{x}$=1.22 Mcal/kg^{-1}. TDN percentage was highest in *Ebenopsis ebano* ($\bar{x}$=80.81), while the lowest was found in *Tabebuia rosea* with $\bar{x}$ =54.64. (Table 3).

Table 3. Energy characterization of six tree forage species in the dry tropics of Sinaloa, Mexico.

Species	DE	NE_m	NE_g	NE_l	TDN
Ebenopsis ebano	3.55[a]	2.34[a]	1.93[a]	1.86[a]	80.81[a]
Acacia farnesiana	3.29[ab]	2.11[b]	1.65[b]	1.71[ab]	74.72[ab]
Tabebuia rosea	2.40[d]	2.56[a]	1.99[a]	1.22[d]	54.64[d]
Lysiloma divaricatum	2.98[bc]	1.91[c]	1.42[c]	1.54[bc]	67.78[bc]
Guazuma ulmifolia	2.86[c]	1.77[d]	1.26[d]	1.47[c]	64.98[c]
Chloroleucon mangense	3.09[bc]	2.00[c]	1.53[c]	1.60[bc]	70.38[bc]
CV (%)	8.63	4.03	6.33	9.28	8.63

Means followed by different superscript letters differ significantly (P<0.05).
DE: Digestible Energy (Mcal/kg-1 MS); NEm: Net Energy for maintenance (Mcal/kg-1 MS); NEg: Net Energy for gain (Mcal/kg-1 DM); NEl: Net Energy for lactation (Mcal/kg-1 MS); TDN (%): Total Digestible Nutrients; % CV: Percentage of Coefficient of variation.

A significant difference (P<0.05) was observed in the accumulation of average GDD per day per forage species (Table 4), while the CV for this variable was 10.65%. The highest amount (P<0.05) of GDD was observed in June with 621.2, followed by July (617) and August (592.8), whereas the lowest accumulation occurred in November, with 442.7. During the 7-month sampling period, the total accumulated GDD was 3 853.60, with a population average of 550.51.

Table 4. Daily GDD averages and monthly accumulated GDD during the sampling period for six tree forage species in the dry tropics of Sinaloa, Mexico.

Month	Average GDD/Day^{-1}	Monthly cumulative GDD
May	16.27^{d}	504.50^{d}
June	20.04^{a}	621.24^{a}
July	19.90^{ab}	617.00^{ab}
August	19.12^{ab}	592.80^{ab}
September	18.64^{bc}	577.84^{bc}
October	17.76^{c}	550.60^{c}
November	14.28^{e}	442.68^{e}
CV	10.65%	TOTAL: 3 853.60; μ: 550.51

Means followed by different superscript letters differ significantly ($P<0.05$).
GDD: Growing degree days; CV: Coefficient of variation.

GDD accumulation on an annual basis (Table 5) showed the differences between the physiological efficiency of these species to produce leaves and root biomass. Leaf area increases the plant´s efficiency in the use of light and water resources for photosynthesis, accelerating growth under favorable environmental conditions.

Table 5. Annual growing degree days (GDD) of six tree forage species in the dry tropics of Sinaloa, Mexico.

Month	Annual GDD
January	258.40
February	273.40
March	315.80
April	403.10
May	504.50
June	601.20
July	617.00
August	592.80
September	559.10
October	550.60
November	428.40
December	298.40

Discussion and conclusions

The order in which the forage trees analyzed are consumed by cattle in the study sites was as follows: *Acacia farnesiana* in the first place, followed by *Chloroleucon mangense*, *Guazuma ulmifolia*, *Ebenopsis ebano*, *Lysiloma divaricatu*m. and *Tabebuia chrysantha* (Table 1). Species abundance, calculated on the basis of tree density, showed *Acacia farnesiana* as the most abundant, followed by *Lysiloma divaricatu*m, *Guazuma ulmifolia*, *Tabebuia chrysantha*, *Chloroleucon mangense,* and *Ebenopsis ebano* with the lowest presence.
In general, the greatest forage potential of trees is found in legume species (Rendón-Sandoval *et al.*, 2020). Giraldo (1996) found that *Gliricidia sepium* contains 35% DM, 25% PDMI, and 2.0 Mcal ME/Kg^{-1} DM. *Erythrina poeppigiana* contains similar values (23% DM, 25% CP, and

2.0 Mcal ME/kg^{-1}), while *Guinea grass* (*Panicum maximum*) presented 19.5% DM, 10.7% CP, and 2.0 Mcal ME/kg^{-1}.

Tree and shrub forages are known to contain relatively high CP values, depending on the species (Benavides, 1991). However, the nutritional value of trees varies in the different components of their biomass, since leaves have a higher concentration of nutrients than branches and stems (Carmona-Agudelo, 2007). The variation has also been related to age and position in the tree: young leaves are higher in protein than old ones, and the latter also have low digestibility percentages due to higher concentrations of lignin and possibly tannins (Benavides, 1991).

Currently, there is an increasing interest in the search for food resources that can partially replace the use of expensive concentrates to provide energy, protein and minerals to cattle (Mendoza-Martínez *et al.*, 2008). In this regard, trees and shrubs play a predominant role due to their high nutritional value and multipurpose nature (Cabrera-Nuñez *et al.*, 2019). Among the numerous tree species with good forage properties, legumes hold an outstanding position (Rendón-Sandoval *et al.*, 2020).

However, there are other perennial woody plants with great potential that have not been used extensively and their use has been limited to specific and isolated feeding systems, such as *Trichanthera gigantea* (Rosales and Ríos Kato, 1999), *Moringa oleifera* (Ramírez, 2017), *Azadirachta indica* (Bijalwan *et al.*, 2017), *Ficus* species (Viswanath *et al.*, 2012), *Tithonia* (Canul-Solis *et al.*, 2018), *Morus alba* (Kant *et al.*, 2004), and *Cnidoscolus* sp. (Aguilar-Luna *et al.*, 2010) mainly due to their great versatility, rapid growth and recovery after cutting, in addition to offering considerable biomass production in the dry period.

Considering the importance of such species for tropical livestock, it is necessary to study comprehensively the main indicators of their bromatological composition, as well as the presence of possible toxic compounds and the levels of secondary metabolites present in the biomass.

Lofgreen and Garrett (1968) elaborated a feeding system that allows recognizing the efficiency in the use of the different metabolizable energies for processes such as metabolism and production. For the use of feeds, two values are taken: net energy for gain (NE_g) and net energy for maintenance (NE_m). Energy retention was estimated at 75 kcal multiplied by live weight raised to the 0.75 power of net energy, $W^{0.75}$, indicating the fasting metabolism of the animal, called net maintenance energy of the animal. For each level of NE_m there is a corresponding level of EN_g (NRC, 2000).

Leaf production is one of the most economically important processes in forage production, as leaves are the basic structures that determine the intensity or speed of growth and make a high contribution to forage quality. It is accepted that the optimal leaf area index (LAI) in forages is the one that implies a maximum growth rate. Pearce *et al.* (1965) consider that an optimal LAI value ranges from 5.5 to 7.

Pearson and Ison (1997) pointed out that energy absorption is determined by LAI, and that grasses can intercept 95% of radiation with a LAI from 6 to 9. Photosynthesis influences the quality of the forage produced, and there are important photosynthetic routes. GDD calculations are one of the simple estimation models (Frank, 1996).

Regarding the nutritional value of forages, functions with a good degree of adjustment have been developed that relate the nutritional value of the forage with the temperature or GDD accumulated during regrowth (Onstad and Fick, 1983). Guerra and Calderón (1977) estimated that the growth and development of forages are affected by GDD. The GDD approach allows calculating the number of leaves produced according to temperature accumulation, thus providing a valuable tool for grazing management decisions (Frank, 1996). Each plant species requires ~~a~~ certain number of GDD to complete its development, presenting certain critical

temperatures (sometimes called cardinal temperatures) that define the heat requirements necessary for its growth and development (Wilson and Barnett, 1983).
These cardinal temperatures include the lowest and highest temperatures at which the plant grows, and the optimum, the temperature at which growth and development are greatest. In addition to cardinal temperatures, there are lethal temperatures, which cause the death of the plant (García *et al.*, 1994). The physiologically effective temperature (GDD) influenced the forage trees studied, which was reflected in differences in the quantity and quality of forage produced. It is necessary to determine the phenological clock based on the GDD for each of the forage species.
Vinolo (*Acacia farnesiana*) is the fodder tree most consumed by cattle and the one with the highest density in the sampled area. Palo pinto (*Chloroleucon mangense*) is the second most important species, despite its low density in the study area. However, ebony was the tree with the best energy characterization, since its energy values (ED, TDN, NE_m, NE_g, NE_l) were higher and more consistent than those of the other species. GDD were higher in the summer season, while the lowest amount occurred in autumn, which was reflected in differences in the quality and quantity of the forage trees studied.
Additional studies are required to determine the amount that can be fed cattle, to determine the amount of anti-nutritional agents they may contain, as well as their *in vivo* digestibility; further studies should include the analysis of a higher number of trees with forage potential and use that specific adaptability values for trees, replacing grass data.

References

AGUILAR-LUNA, J.M.E.; MACARIO, P.; HUERTA, E.; HERNÁNDEZ, S. and ALBA, R. (2010). Crecimiento y productividad de chaya (*Cnidoscolus chayamansa* McVaugh, Euphorbiaceae) con densidad de plantación variable. Cultivos Tropicales, 31(4), 1-8.

AOAC. (1999). Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Arlington, V.A., USA.

BARRERAS, S.A.; HERRERA H.J.G. and GUERRA, L.J.E. (1999). Análisis Estadístico de Experimentos Agropecuarios Utilizando el Sistema SAS (Statistical Analysis System). Universidad Autónoma de Sinaloa. pp 71-74. Sinaloa, México.

BEIGH, Y.A.; GANAI, A.M. and AHMAD, H.A. (2017). Prospects of complete feed system in ruminant feeding: A review. Veterinary World, 10(4), 424–437.

BENAVIDES, J.E. (1991). Integración de árboles y arbustos en los sistemas de alimentación para cabras en América Central: un enfoque agroforestal. El Chasqui (C. R.), 25, 6-35.

BOTERO, R. and RUSSO, R.O. (1998). Utilización de árboles y arbustos fijadoras de nitrógeno en sistemas sotenibles de producción animal en suelos ácidos tropicales. In: Rosales M. y Sánchez M.D. (eds)Agroforestería para la producción animal en Latinoamérica (electronic conference), pp. 171–192. Rome: FAO. Disponible en: http://lead-es.virtualcentre.org/es/ele/ conferencia1/Agrofor1.htm

CABRERA-NÚÑEZ, A; LAMMOGLIA-VILLAGOMEZ, M.; ALARCÓN-PULIDO, S.; MARTÍNEZ-SÁNCHEZ, C. and ROJAS-RONQUILLO, R. (2019). Árboles y arbustos forrajeros utilizados para la alimentación de ganado bovino en el norte de Veracruz, México. Abanico Veterinario, 9: e913.

CANUL-SOLIS, J.R.; CASTILLO-SÁNCHEZ, L.E.; ESCOBEDO-MEX, J.G.; LÓPEZ-HERRERA, M.A. and LARA Y LARA, P.E. (2018). Forage yield and quality of *Gliricidia sepium*, *Tithonia diversifolia* and *Cynodon nlemfuensis* in monoculture and agroforestry systems. Agrociencia, 52(6): 853-862.

CARMONA-AGUDELO, J.C. (2007). Efecto de la utilización de arbóreas y arbustivas forrajeras sobre la dinámica digestiva en bovinos. Revista Lasallista de Investigación, 4(1): 40-50.

COOPER, D.S. (1992). Recursos fitogenéticos (on line). Ed. Geneflow. Disponible en: http://www.colciencia.gov.co/Amazonia/Corpoinca/inter62.htm

CRESPO, G. (2015). Factores que influyen en el reciclaje de nutrientes en pastizales permanentes, avances en el desarrollo de su modelación. Revista Cubana de Ciencia Agrícola, 49 (1): 1-10.

EDWARDS-CALLAWAY, L.N.; CAITLIN-CRAMER, M.; CADARET, C.N.; BIGLER, E.J. and ENGLE, T.E. (2021). Impacts of shade on cattle well-being in the beef supply chain. Journal of Animal Science, 99(2): skaa375.

FRANK, A.B. (1996). Evaluating grass development for grazing management. Rangelands, 18 (3):106.

GARCÍA, C.R.; CONTRERAS, M.G. and GONZÁLEZ, E.D. (1994). Índices agroclimáticos derivados de la temperatura para el Valle de Mexicali, B. C., México. Universidad Autónoma de Baja California. Instituto de Ingeniería. Mexicali, B.C., México.

GARCÍA, E. (1987). Modificaciones al sistema de clasificación climática de Köpen. Cuarta Edición. Inst. de Geografía. UNAM. México, D. F. 90 p.

GIRALDO, L.A. (1999). Potencial del guácimo (*Guazuma ulmifolia*) en sistemas silvopastoriles. En Sánchez, M.D. y Rosales, M., (eds.), Agroforestería para la producción animal en América Latina. Estudio FAO Producción y Sanidad Animal 143, pp 295-310. Roma, Italia.

GOERING, H.K. and VAN-SOEST, P.J. (1970). Forage fiber analysis (apparatus, reagents, procedures and some applications) Agric. Handbook. No. 379. ARS. USDA. Washington, D. C. 20 p.

GOVINDARAJ, M.; VETRIVENTHAN, M. and SRINIVASAN, M. (2015). Importance of genetic diversity assessment in crop plants and its recent advances: an overview of its analytical perspectives. Genetics Research International, (2015): 431487.

GUERRA, L.J.E. and CALDERÓN, D. (1997). Crecimiento comparativo y grados días calor (GDD) en ryegrass (*Lolium multiflorum* L.) solo y asociado. *En*: Memoria del Simposium Internacional y IV Reunión de Nutrición Animal. Universidad Autónoma de Nuevo León. pp.158-160. Marín, N. L. México.

GUERRA, L.J.E.; SALCEDO, A.U.; MORENO, J.H.; CORRALES, J.L. and SOTO, L.E. (1999). Efecto de los grados días crecimiento (GDD) en índice de área foliar y producción de hojas en zacate Bermuda (*Cynodon spp*). *En*: Memoria del XX Congreso Nacional y Simposium Internacional de la Ciencia de la Maleza. 29-30 de septiembre y 1 de octubre. Universidad Autónoma de Sinaloa-ASOMECIMA, pp 204-209. Culiacán Sinaloa, México.

KAMAL, R.; DUTT, T.; PATEL, M.; DEY, A.; BHARTI, P. and CHINNAKKAN, C. (2018). Heat stress and effect of shade materials on hormonal and behavior response of dairy cattle: a review. Tropical Animal Health and Production, 2018(50): 701-706.

KANT, R.; CHAKRABARTY, S.; DHYANI, S.K. and UPADHAYAY, R.K. (2004). Mulberry (*Morus alba* L.) as an agroforestry plant in Uttaranchal. The Indian Forester, 130(8): 939-944.

KAUSHAL, R.; PANWAR, P.; SARV, S.; SARVADE, S.; TOMAR, J.S.M. and CHATURVEDI, O.P. (2017). Agroforestry for Biodiversity Conservation. In: Gupta, S.K.; Panwar, P.; Kaushal, R. (Eds.) Agroforestry for Increased Production and Livelihood Security (pp. 363-378). New India Publishing Agency. New Delhi, India.

LOFGREEN, G.P. and GARRETT, W.N. (1968). A system for expressing net energy requirements and feed values for growing and finishing cattle. J. Anim. Sci., 27:793–806.

LUCERO-IGNAMARCA, A.; MUÑOZ-SÁEZ, F.; CANCINO-CANCINO, J.; SOTOMAYOR-GARRETÓN, J.A. and DUBE, F. (2019). La cobertura arbórea de *Acacia caven* sobre la calidad de la pradera y microclima en un sistema silvopastoril de Chile central. Madera y Bosques, 25(2): e2521811.

LÜSCHER, A.; MUELLER-HARVEY, I.; SOUSSANA, J.F.; REES, R.M. and PEYRAUD, J.L. (2014). Potential of legume-based grassland-livestock systems in Europe: a review. Grass and forage science: The Journal of the British Grassland Society, 69(2): 206–228.

MEILI, N.; MANOLI, G.; BURLANDO, P.; CARMELIET, J. and WINSTON, T. (2021). Tree effects on urban microclimate: Diurnal, seasonal, and climatic temperature differences explained by separating radiation, evapotranspiration, and roughness effects. Urban Forestry & Urban Greening, 58(2021):126970.

MÉNDEZ R.M. 1998. Mezclas forrajeras: uso de la diversidad forrajera tropical en sistemas agroforestales. (en línea). Conferencia electrónica de la FAO. Disponible en: http://www.fao.org/ag/aga/agap/FRG/AGROFOR1/Rosales9.htm

MENDOZA-MARTÍNEZ, G.D.; PLATA-PÉREZ, F.X.; ESPINOSA-CERVANTES R. and LARA-BUENO, A. (2008). Manejo nutricional para mejorar la eficiencia de utilización de la energía en bovinos. Universidad y Ciencia, 24(1): 75-87.

NITIS, I.; LANA, K.; SUKANTEN, W. and SUARNA, M. (1990). The concepts and development of the three-strata forage system. In: Shrubs and tree fodders for farm animals. Pp. 92-102. Edited by Devendra. Indonesia.

NRC. 2000. Nutrient Requirements of Beef Cattle. Seventh Revised Edition. National Academy Press. Washington, D. C. 248 p.

ODALYS, C.; PÉREZ, T. and IGLESIAS, J.M. (2008). Selectividad de especies arbóreas potencialmente útiles para sistemas de producción ganaderos. Zootecnia Tropical, 26(3): 197-200.

ONSTAD, D.W. and FICK, G.W. (1983). Predicting crude protein, *"in vitro"* true digestibility and leaf proportion in alfalfa herbage. Crop Sci., 23:961-964.

ORTEGA-GÓMEZ, R.; CASTILLO-GALLEGOS, E.; JARILLO-RODRÍGUEZ, J.; ESCOBAR-HERNÁNDEZ, R. and OCAÑA-ZAVALETA, E. (2011). Nutritive quality of ten grasses during the rainy season in a hot-humid climate and ultisol soil. Tropical and Subtropical Agroecosystems, 13(3):481-491.

PEARCE, R. B., BROWN, R. H., & BLASER, R. E. (1965). Relationship between leaf area index, light interception and net photosynthesis in orchard-grass.

PEARSON, C.J. and ISON, R.L. (1997). Agronomy of Grasslands Systems. 2nd Ed. Cambridge University Press. 236 p.

RAMÍREZ-BUILES, V.H. (2007). Los sistemas agroforestales en el trópico y la fertilidad del suelo. Investigaciones de Unisarc, 5(2):11-21.

RAMÍREZ, J.E. (2017). *Moringa oleífera* (Lam.) en condiciones de bosque seco tropical: una revisión. Revista Agroforestería Neotropical, 1(7): 2017).

RENDÓN-SANDOVAL, F.J.; CASAS, A.; MORENO-CALLES, A.I.; TORRES-GARCÍA, I. and GARCÍA-FRAPOLLI, E. (2020). Traditional agroforestry systems and conservation of native plant diversity of seasonally dry tropical forests. Sustainability, (2020), 12: 4600.

ROSALES, M. and RÍOS-KATO, C.I. (1999). Avances en la investigación en la variación del valor nutricional de procedencias de *Trichanthera gigantea.* In: Sánchez M.D. y Rosales-Méndez M. (Eds.) Agroforestería para la producción animal en América Latina. Organización de las Naciones Unidas Para la Agricultura y la Alimentación. Pp 351-389. Roma, Italia.

SAS, 2009. SAS User's Guide (Release 9.1): Statistics SAS Inst. Inc., Cary. N. C.

SALISBURY, F.; ROSS, C.; GONZÁLEZ-VELÁZQUEZ, V.; PALACIOS-MARTÍNEZ, R. and GREPE-PHILIP, N. (1994). Fisiología Vegetal. Grupo Editorial Iberoamérica. Colombia. 756 p.

SCHEAFFER, R.L.; MENDENHALL, W. and OTT, L. (1987). Elementos de muestreo. Grupo Editorial Iberoamérica. México, DF. México. 321 p.

SHINOZAKI, K.; YODA, K.; HOZUMI, K. and KIRA, T. (1964). A quantitative analysis and its application in forest ecology. Japanese Journal of Ecology, 14: 133-139.

TJELELE, J.; WARD, D. and DZIBA, L. (2015). The effects of seed ingestion by livestock, dung fertilization, trampling, grass competition and fire on seedling establishment of two woody plant species. PloS One, 10(2): e0117788.

TREITLER, J.T.; DRISSEN, T.; STADTMANN, R.; ZERBE, S. and MANTILLA-CONTRERAS, J. (2017). Complementing endozoochorous seed dispersal patterns by donkeys and goats in a semi-natural island ecosystem. BMC Ecology 17: 42.

TORRES-GUERRERO, C.A.; ETCHEVERS, J.D.; FUENTES-PONCE, M.H.; GOVAERTS, B. and LEÓN-GONZÁLEZ, F.D. (2013). Influencia de las raíces sobre la agregación del suelo. Terra Latinoamericana, 31(1): 71-84.

VISWANATH, S.; BHASKAR, D. and PURUSHOTHAMAN, S. (2012). Ficus trees. Journal of Tropical Agriculture, 50: 59-62.

WAGNER, J.B. (2013). Las arbóreas Una alternativa nutricional en la producción animal. Disponible en: http://www.produccion-animal.com.ar/produccion_y_manejo_pasturas/manejo %20silvopastoril/163-arboreas.pdf

WILSON, L.T. and BARNETT, W.W. (1983). Degree-days: an aid in crop and pest management. California Agriculture, 37 (1): 3-7

CASTRO-CAMACHO, S. J., AVENDAÑO-REYES, L., SOTO-NAVARRO, S., VALENZUELA-NÚÑEZ, L. M., ANGULO-CASTRO, A., LEE-RANGEL, H. A., … MEJIA-DELGADILLO, M. A. (2024). Caracterizaciones bromatológicas y energéticas de seis especies de árboles con potencial forrajero en la región tropical seca en Sinaloa, México. *Ciencias Agronómicas*, (44), e044. https://doi.org/10.35305/agro44.e044

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