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DENSITY AND INTEGRAL USE EVALUATION OF THREE LEGUMINOUS TREES IN SILVOPASTORAL SYSTEMS IN THE TROPIC OF GUERRERO, MEXICO

EVALUACIÓN DE LA DENSIDAD Y USO INTEGRAL DE TRES ÁRBOLES LEGUMINOSOS EN LOS SISTEMAS SILVOPASTORILES EN EL TRÓPICO DE GUERRERO, MÉXICO

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RESUMEN: En el Trópico Méxicano se estudió la distribución, densidad y usos de los árboles *Pithecellobium dulce* Roxb Benth, *Gliricidia sepium* (Jacq) Steud, *Haematoxilum brasiletto* Karst y se agregó su follaje a las dietas de cabritos y midió la respuesta productiva y la digestibilidad aparente. Los ganaderos dieron seis usos (leña, postes, sombra, medicinales, consumo humano y artesanal). Los árboles estuvieron en cercas vivas y dispersos en potreros con densidades de 4,87 árboles 100^{-1} metros lineales y 1,79 árboles ha^{-1}; *P. dulce* Roxb Benth tuvo mayor talla y se localizó entre 250 a 1332 msnm. Las cenizas (P<0,0001) y fibras detergentes (P<0,01) del *P. dulce* (T1) fueron más digestibles. La CA y GDP entre los cabritos fueron diferentes entre tratamientos. La temperatura rectal sólo se afectó (P<0,0001) por la hora de evaluación. El pH ruminal de los cabritos fue diferente entre tiempos de evaluación (P<0,0001) y tratamientos (P<0,0003). Se concluye que la densidad de árboles es baja y podría tener un impacto sobre la fertilidad del suelo y la aportación de biomasa para la alimentación animal; La digestibilidad de las dietas y respuesta productiva fueron más eficientes en los animales alimentados con *P. dulce* Roxb Benth (T1).
Palabras clave: alimentación, leguminosas, pH, rumiante, digestibilidad aparente

ABSTRACT: In the Tropic of Guerrero Mexico the distribution, the density and uses of trees *Pithecellobium dulce* Roxb Benth, *Gliricidia sepium* (Jacq) Steud,

Haematoxilum brasiletto Karst were studied and its foliage was added to the diets of kids and productive response and apparent digestibility was measured. The livestock farmers have six complementary uses (firewood, poles, shade, medicinal, human consumption and artisanal). The species were identified in live fences and scattered in paddocks with densities of 4.87 trees per 100 linear meters and 1.79 trees ha^{-1}; *P. dulce* was the largest size and identified from 250 to 1332 masl. The ashes (P<0.0001) and detergent fibre (P<0.01) of *P. dulce* (T1) had higher apparent digestibility. The feed conversion and daily weight gain of the kids were different due to the effect of foliage trees. The rectal temperature was only affected (P<0.0001) by the time of evaluation. The ruminal pH of kids was affected by time evaluation (P<0.0001) and the treatments (P<0.0003). It is concluded that the density of trees is low and could be of impact on soil fertility and the contribution of biomass for animal feed; the apparent digestibility of diets and productive response were more efficient in the animals fed with *P. dulce* (T1).
Key words: feeding, legumes, pH, ruminant, apparent digestibility.

INTRODUCTION

Fodder trees in silvopastoral systems are an important component from the environmental point of view that can reduce soil erosion, to act as a carbon sink and integrate great amounts of organic matter and nitrogen to the soil. Moreover backgrounds suggest that in cattle ranches the trees can be used for various services such as natural shade, for obtaining wood (beams, wooden posts and poles for rural construction), as medicine and food for animals (Olivares-Pérez *et al*., 2016). Has been shown that the foliage can be used in the control of intestinal parasites and thus increase the productivity in goats (León-Castro *et al*., 2015) this because tannins are compounds found in the leaves and / or fruit of the trees and they can have an effect against parasites (Patra & Saxena, 2011; Rojas-Hernández *et al*., 2016; Williams *et al*., 2014). The density of the fodder trees is important in the prairies, if the density is high can contribute to maintain and / or restore degraded soils (Olivares-Pérez *et al*., 2016; Reis *et al.*, 2010), in addition, the contribution of biomass useful as animal feed is higher as well (Rojas-Hernández *et al*., 2016). The biomass of trees as an alternative feed for ruminants has been used in several studies with positive results in animal response (the dry matter intake, weight gain, feed conversion and diet digestibility) (Olivares *et al.*, 2013; Olivares Perez *et al.*, 2013; Rojas-Hernandez *et al.*, 2015; Rojas Hernández *et al.*, 2015). However a constraint to use the arboreal resource as food is its tannin content, these compounds in high concentrations can confer organoleptic characteristics to food that reduce the palatability and consumption of dry matter in animals (Lee *et al*., 2015; Patra & Saxena, 2011). In addition, reports indicate that tannins have defaunate effect and are capable of binding to dietary nutrients (protein, fiber and carbohydrates) and affect digestibility and reduce animal productivity (Lorenz *et al.*, 2014; Patra & Saxena, 2011). It has also been reported that changes in ruminal pH outside its range may have an impact on the health of ruminant animals and the factor most closely related is the food type they receive in the diet (Chibisa *et al.*, 2016; Lee *et al.*, 2015; León-Castro *et al*., 2015). The objectives were to study the distribution, density and uses of trees *Pithecellobium dulce* Roxb Benth, *Gliricidia sepium* Jacq Steud and *Haematoxilum brasiletto* Karst and add foliage to diets for kids and measure the productive response and apparent digestibility.

MATERIAL AND METHODS

Location of the experimental site

The study was conducted in the Tropical region of Guerrero, Mexico located at 18° 20` 30" NL and 100° 39` 18" WL. The climate that prevails is the Aw0, is the driest of the sub humid warm with summer rains. The average temperature and rainfall are of 28°C and 1010.7 mm.

Descriptive study

Location, distribution, uses and dasometric measures: The information on uses of trees was obtained by direct interviews 81 livestock farmers in the study area. The location and distribution was assessed and measures dasometric trees were recorded in four plots transects at each ranch. Each transect was one ha for scattered trees in pastures and hundred linear meters (L) for trees in live fences.

Experimental study

Foliage Collection: The foliage of *Pithecellobium dulce* Roxb Benth, *Haematoxylum brasiletto* Jacq Steud and *Gliricidia sepium* Karst were collected manually by pruning trees and dehydrated by exposure to solar rays to constant weight (on average 88% of dry matter). The dehydrated foliage was milled in a hammer mill to a particle size of five mm on average and were integrated to rations of goat kids.

Management of animals

Experimental animals: 15 weaned male Creole kids were used with an average, average live weight of 14 ± 3 kg from existing herds in the study area, used to graze the native vegetation from birth. The animals were kept in individual pens with a vital space (2 m^2), with free access to drinking trough and manger where treatments were given. At the beginning of the experiment the kids were dewormed subcutaneously with ivermectin at doses of 0.2 mg / kg body weight (Sumano & Ocampo, 2006).

Treatment assignment: Kids are distributed through a completely randomized design in three treatments that were provided ad libitum for 68 days (8 days of adaptation and 60 days of evaluation). Treatments were, isoproteic (11.0%) and isocaloric diets (10.5 Mj ME kg DM) added with 30% of foliage *Pithecellobium dulce* Roxb Benth (T1), *Gliricidia sepium* Jacq Steud (T2) and *Haematoxylum brasiletto* Karst (T3) (table 1) prepared according to the nutritional requirements of animals (Nutritionals Research Council (NRC), 2007). The final diets were analyzed for content of acid (ADF) and neutral (NDF) detergent fiber with the Van Soest and Wayne method (Van Soest & Lewis, 1991) and the ash content (Ce), organic matter (OM) and crude protein (CP) according to the AOAC methods (Association of Official Analysis Chemists International (AOAC), 2000).

Measures variables

Animal response: Nutrient intake (dry matter, organic matter, protein, neutral detergent fiber and acid) were measured and obtained by multiplying the daily consumption of DM by the content of each nutrient in the diet (table 1). Weight change and dry matter intake were recorded. The live weight was measured with an electronic scale with capacity of 500 kg and graduated in grams; the dry matter intake (DMI) was determined by subtracting the amount offered from the amount rejected daily. The daily weight gain (DWG) was estimated by subtracting the final weight, the initial weight and divided between the days of the study. The feed conversion (FC) was calculated by dividing the feed intake between the DWG.

Rectal temperature: The inclusion of foliage of trees in diets that constituted the treatments, can bring toxic substances for goats (condensed tannins, CT) that in some situations compromise the thermoregulatory capacity of the animals. For this reason, during the last seven days of the experiment with the animals of each treatment the rectal temperature was measured at three times (07:00, 13:00 and 18:00 h) with an electronic thermometer graduated in degrees Celsius.

Apparent digestibility of nutrients from the diet: For seven days, all animals' faeces were collected using harnesses collectors placed on each adapted animal during fourteen days. For the collected faeces the content of DM, OM, CP, ADF and NDF were determined. Known nutrient content in the diet and faeces and the apparent digestibility of the diet (DM, OM, CP, ADF and NDF) were calculated, using the equation (International Livestock Centre for Africa (ILCA), 1990):

$$Digestibility\ (\%) = \frac{\text{Comsumption} - \text{Fecal excretion}}{\text{Consumption}}\ x\ 100$$

Where, Digestibility (%) is the nutrient digestibility, consumption is equal to consumed nutrient, faecal excretion represents each nutrient excreted in the faeces.

Measuring of ruminal hydrogen potential (pH): On the last day of the experiment of each animal 60 mL of ruminal fluid were collected at different times (0, 1, 3 and 6 h post feeding), immediately after collection using a potentiometer was measured ruminal pH fluctuation as indicative of the environmental condition for the fermentative rumen microflora activity.

Table 1. Ingredients and chemical composition of treatments with fruits, dry basis quantities (DM)

Ingredient (kg / 100 kg DM)	T1	T2	T3	SEM
Foliage of *P. dulce*	30.0			
Foliage of *G. sepium*	-	30.0	-	-
Foliage of *H. brasiletto*	-	-	30.0	-
Ground corn	6.0	0.0	-	-
Ground cob	61.0	65.0	61.0	-
Soybean meal	2.0	4.0	8.0	-
Mineral premix	1.0	1.0	1.0	-
Totals DM (kg)	100.0	100.0	100.0	-
Chemical composition (% DM)				
Crude protein	11.7	12.0	12.6	-
Ashes	3.9	3.9	2.9	2.6
Organic matter	96.0	96.0	97.0	2.7
Neutral detergent fibre	33.3	27.5	38.3	5.6
Acid detergent fibre	14.6	13.7	17.8	0.5
ME Mj / kg DM	11.3	11.0	11.4	-
In vitro gas production (96 h, mL / g DM)	277.8[a]	236.0[b]	235.4[b]	5.8

T1: *P. dulce* 30%; T2: *G. sepium* 30%; T3: *H. brasiletto* 30% SEM: standard error of the means

Statistical analysis

Descriptive study: The location, distribution, uses, density and trees dasometric measures by descriptive statistics (Steel & Torrie, 2006).

Experimental study: The data of variables of animal response (dry matter intake and nutrient apparent digestibility, daily weight gains and feed conversion) were analysed by variance according to a completely randomized design with the statistical model $Y_{ij} = \mu + \tau i + \xi ij,$ where Y_{ij} is the response variable, μ is the overall mean, τi treatment effect i (1, 2 and 3 treatments) and ξij is random error attributed to the ith treatment in the jth repetition (1, 2 ... 5 male kids).

The rectal temperature and ruminal pH data were analysed in a completely randomized design in 3 x 3 factorial arrangement (three forages for three times as rectal temperature, 7:00, 13:00 and 18:00 respectively) and 3 x 4 (three times foliage's four ruminal pH measurement, 0, 1, 3 and 6 h post-feeding, respectively); statistical model $Y_{ijk} = \mu + Ai + Bj + (AB)_{ij} + \xi_{ijk}$; Where: Y_{ijk} = rectal temperature, μ is the general mean; Ai is the treatment effect (i = 1, 2 and 3 treatments) is the measured times Bj effect; $A * B_{ij}$ is the first-order interaction and ξ_{ijk} is the mistake in terms of n-1 (σ^2, 0) (SAS, 2002).

Correlation analysis (r) were developed to determine the relationship between measurement times (hours) with ambient temperature (AT) and rectal temperature (RT) of animals and regression analysis (r^2) were performed between times measurement and AT with RT animal. The averages of the evaluated variables were compared with the Tukey test ($P < 0.05$) (SAS, 2002).

RESULTS

Descriptive study

Location, density and uses of trees: In figure 1, letter "a" shows that the *P. dulce* Roxb Benth adapts to a wide range of altitudes from 250 masl to 1 332 masl compared with the trees of *G. sepium* Jacq Steud and *H. brasiletto* Karst that were located up to 455 and 512 masl respectively. In addition, the three trees are distributed in arrangement of live fences and scattered trees in 85.3 and 75.5% of the transects evaluated in livestock ranches (fig. 1, item b), with an average density of 4.87 ± 1.4 trees per 100 m linear and in live fences of 1.79 ± 0.5 trees per ha in the rangeland (fig. 1, item c).

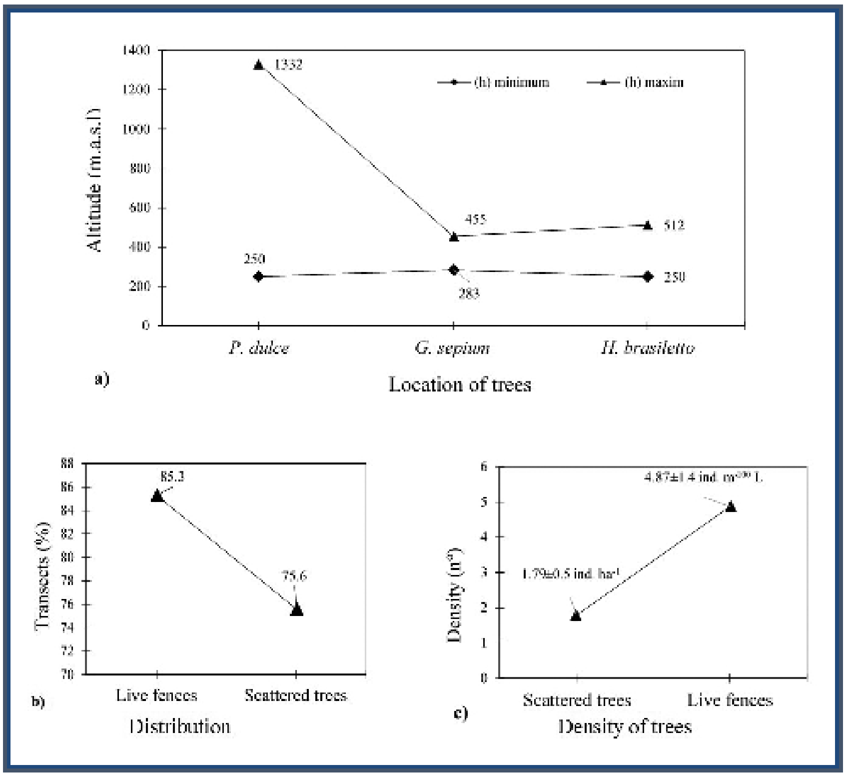

Fig. 1. Location (masl), distribution and density of forage trees in livestock ranches in the Tropical Region of Guerrero Mexico.

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In addition to the feed, identified six complementary uses were (firewood, poles, shade, medicinal, human consumption and artisanal) for which farmers use *P. dulce* Roxb Benth, four at *H. brasiletto Karst* (firewood, poles, shade, and medicinal) and only two for *G. sepium* Jacq Steud (shade and medicinal). Although the *P. dulce* Roxb Benth has a greater dasometric size, the trees of *H. brasiletto* Kast and *G. sepium* Jacq Steud reach a development that allows them to be used equally as shade for cattle in pens and grazing areas (table 2). The medicinal uses were to counter diabetes (*G. sepium* Jacq Steud) for the kidney (*H. brasiletto* Karst) and as dewormer (*P. dulce* Roxb Benth) (fig. 2).

Table 2. Dasometric measures and complementary uses of fodder trees in livestock ranches in the Tropical Region of Guerrero, Mexico.

Scientific name	*P. dulce*	*G. sepium*	*H. brasiletto*
Dasometric measures			
Basal diameter (cm)	128	76.4	62.0
Diameter breast height (cm)	95.7	62.1	58.8
Height (m)	12.3	9.2	8.3
Additional uses of trees			
Firewood	✓	-	✓
Posts	✓	-	✓
Shade	✓	✓	✓
Medicinal	✓	✓	✓
Human consumption	✓	-	-
Handicraft	✓	-	-

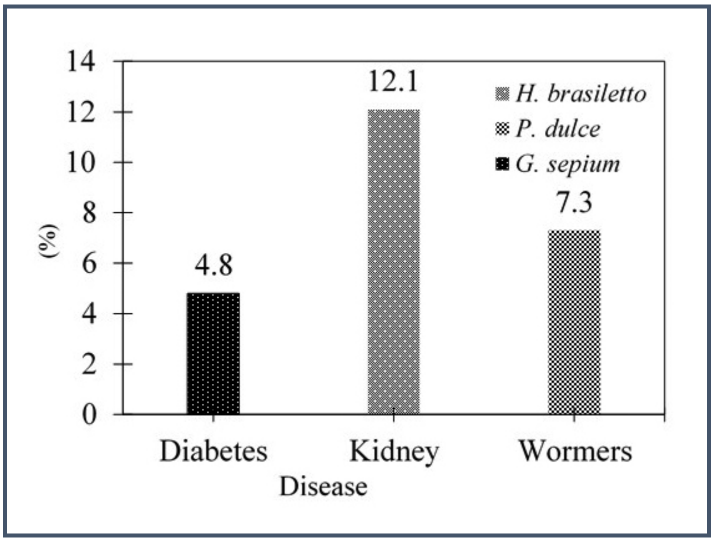

Fig. 2. Main medicinal uses of fodder trees in livestock ranches in the Tropical Region of Guerrero, Mexico.

Experimental study

Animal response: The nutrient intake (DM, NDF, ADF and CP) was not different (P > 0.05) among kids who received the different treatments (T1, T2 and T3) (Table 3). The daily weight gain was higher (P < 0.002) in kids fed with the T1 (127.4 g) and T2 (89.0 g) added with foliage *P. dulce* Roxb Benth and *G. sepium* Jacq Steud, respectively, and feed conversion was higher (4.8 kg DM) (P < 0.03) in the kids fed with the diet added with foliage of *P. dulce* Roxb Benth (T1).

The values of apparent digestibility of the different diets (T1, T2 and T3), show that the NDF and the ashes contained in the diets were more utilized by kids of T1 with foliage of *P. dulce* Roxb Benth, additionally this relates with the biggest weight gain and best feed conversion shown by animals (table 3).

Table 3. Consumption of dry matter and nutrients, daily weight gain and feed conversion of growth kids fed diets containing foliage of *P. dulce*, *G. sepium* and *H. brasiletto*.

Treatments	T1	T2	T3	SEM	Significance
Dry matter intake (g / day)	606.5	567.6	594.3	57.5	0.71
Crude protein intake (g / day)	70.9	68.1	74.8	22.6	0.96
Neutral detergent fibre intake (g / day)	201.9	156.1	227.6	62.3	0.41
Acid detergent fibre intake (g / day)	88.5	77.7	105.8	28.4	0.51
Metabolizable energy intake (Mj / day)	6.8	6.2	6.7	1.8	0.20
Daily weight gain (g)	124.7[a]	89.0[a]	47.0[b]	15.5	0.002
Feed conversion (g)	4.8[a]	6.3[ab]	13.9[b]	3.5	0.03
Apparent digestibility (%)					
Dry matter	73.5	73.6	72.6	2.9	0.90
Organic matter	75.3	74.0	73.1	2.9	0.66
Acid detergent fibre	38.0[a]	25.4[b]	51.5[a]	7.4	0.01
Neutral detergent fibre	57.3[a]	39.6[b]	54.2[a]	5.2	0.01
Crude protein	73.1	73.6	72.3	3.5	0.90
Ashes	61.4[a]	57.6[a]	28.7[b]	3.5	0.0001

T1: *P. dulce* 30%; T2: *G. sepium* 30%; T3: *H. brasiletto* 30% SEM: Standard error of the means; [abc] Different literal values in the same row are different, Tukey (P<0.05).

Rectal temperature: The rectal temperature of the animals did not differ by treatment (P > 0.210), however an effect of evaluation time (P < 0.0001) (table 4) was observed. The rectal temperature gradually increased during daylight hours and ranged between 38.4 ° and 38.7°C at 07:00 h to 39.3° and 39.5°C for 18 h. Figure 3 shows that the day brightness hours is correlated (r) with environmental temperature and the rectal temperature of the animals; furthermore the regression analysis (r^2) shows that the variation in rectal temperature of the kids depend directly on the assessment time and environmental temperature. *Ruminal pH*: The ruminal pH was higher (P < 0.0003) in kids fed with the T1 with 6.49 on average in relation to animals of the T2 and T3. It was also observed that the pH gradually decreased (P < 0.0001) six hours after feeding the animals, ie the pH oscillate between 6.51 and 7.07 at zero hour and between 6.24 and 6.42 to the sixth hour after feeding (table 4). In addition to the independent effects, interactive effect were observed (P < 0.003) between treatments by time (hours) pH assessment after feeding the animals.

Table 4. Rectal temperature and ruminal pH behaviour of kids fed diets added with fodder trees foliage

Treatment diet	Time (hours)	Rectal temperature (ºC)	*Time (hours)	Ruminal pH
T1 (30% foliage of *P. dulce*)	07:00	38.7[bc]	0	7.07[a]
	13:00	39.1[abc]	1	6.35[bcd]
	18:00	39.5[a]	3	6.29[bcd]
			6	6.59[cb]
Means		-		6.57[i]
T2 (30% foliage of *G. sepium*)	07:00	38.7[bc]	0	6.63[b]
	13:00	38.9[ab]	1	6.24[cd]
	18:00	39.3[ab]	3	6.23[d]
			6	6.28[bcd]
Means		-		6.34[ii]
T3 (30% foliage of *H. brasiletto*)	07:00	38.4[c]	0	6.51[bcd]
	13:00	38.9[ab]	1	6.32[bcd]
	18:00	39.3[ab]	3	6.39[bcd]
			6	6.42[bcd]
Means		-		6.41[ii]
Standard error of the means		0.27		0.12
Significance				
Treatments		0.210		0.0003
Time		< 0.0001		< 0.0001
Treatments * Time		0.8800		0.003

[abcd] Values with different letters in the same column are different, Tukey ($P<0.05$)
[i, ii] Differences between treatment means, Tukey ($P<0.0003$)
* Measurements according to the feeding schedule

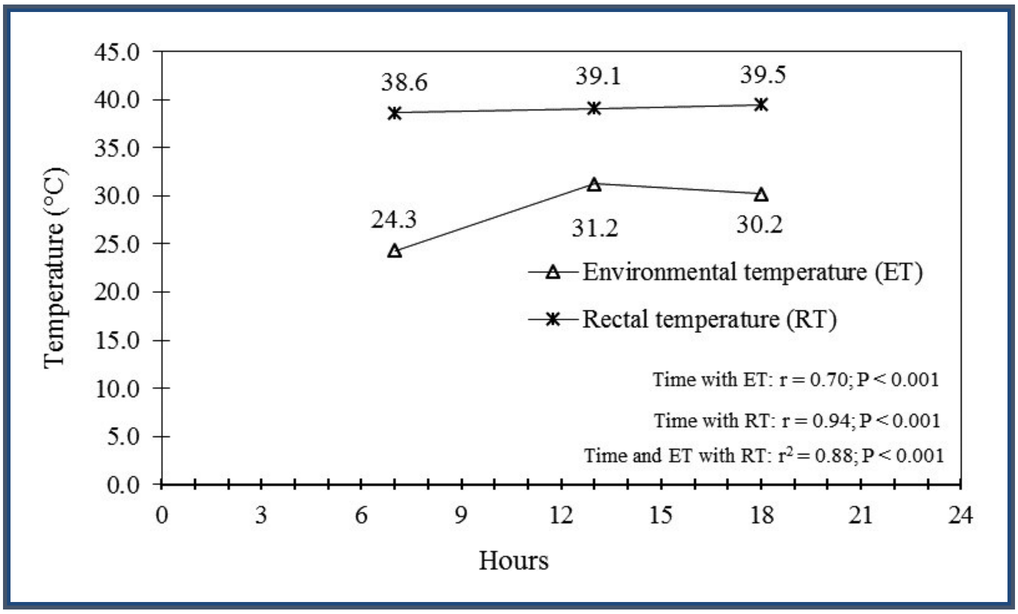

Fig. 3. Correlation and regression between the independent variable time (three hours a day) and ambient temperature with a rectal temperature goat kids as the dependent variable.

DISCUSSION

Descriptive study

Location, density and uses of trees: The information in the figure 1 indicates that the presence of these trees in cattle ranches is very common, however the same density is very low compared to densities of 50 trees ha^{-1} reported in other studies (Cajas-Giron & Sinclair, 2001). This assumes that the negative effects of the trees on pastures require control by cutting or burning, and are stronger than the beneficial effects that farmers get, however, diversified use can promote an increase in tree density (Olivares-Pérez *et al.*, 2016).

Based on the everyday complementary uses that livestock farmers give to the trees demonstrate the need to implement an integral handling of the arboreal stratum that mitigates environmental degradation, promote diversified use and increased density per surface unit, because it may represent a savings in maintenance costs of fences, construction of artificial shade, herbal medicine and in buying feed for animals among other things (Guerreiro *et al*., 2015; Olivares-Pérez *et al.*, 2016; Tálamo *et al*., 2015).

Experimental study

Animal response: The dry matter intake it was not different (table 3), however Olivares *et al*., (2013) report differences in kids fed with foliage of different trees and different level of inclusion in the diet. Contrary reported no differences in dry matter intake by goats fed diets with different levels of inclusion of *Erythrina brucei* Schweinf (Yinnesu & Nurfeta, 2012).

The behaviour in FC of the animals is attributed to the greater weight gain of goat kids of T1, without requiring a significant increase in the consumption of dry matter compared to kids of the T2 and T3 (table 3). Also studies report weight gains and feed conversion higher in kids fed with foliage of *P. dulce* Roxb Benth and *G. sepium* Jacq Steud (Olivares *et al*., 2013). In research developed with the use of biomass of trees similar results were reported in weight gain and feed conversion in ruminants (Oni *et al*., 2008; Sanon *et al*., 2008; Tamir & Asefa, 2009; Thang *et al.*, 2009).

The greater apparent digestibility of the ash fractions and NDF in the diet of T1 with foliage of *P. dulce* Roxb Benth (table 3) favored the weight gain and the feed conversion of the animals. The fraction of ashes due to the contribution of minerals and the fraction of NDF by the contribution of energy to the activity of microbial flora in the rumen (Hamed & Elimam, 2009; Kumara *et al*., 2009; Olivares-Pérez *et al*., 2013). Furthermore, it has been observed that a mineral deficiency in ruminant diet can cause a decrease in the rumen microbial growth and affect the fermentative activity of bacteria on the fibre (Feng *et al*., 2013). Also in ruminants decreased dry matter intake and the digestibility of diets deficient in phosphorus (Feng *et al.*, 2013).

Rectal temperature: The results in rectal temperature of the animals (Table 4) indicated that the variation in this physiological constant was attributed to an increase in brightness and accumulation of heat during the day and not the caloric increase arising from the digestion of diets added with some of the foliage of the trees. The correlation and regression analyses of the Figure 3 confirm that the rectal temperature was directly related to the ambient temperature and the time of day in which the physiological constant was evaluated. Also Catanese *et al*., (2014) who found that lambs supplemented with condensed tannins at concentrations of between 3.0 and 7.7 g / 100 g DM, did not change the rectal temperature of the animals out of their normal range 38.3 to 39.9°C (Fielder, 2015), and equally fluctuations in rectal temperature were attributed to environmental factors.

Ruminal pH: Although the results indicate differences in the ruminal pH between kids by the effect of treatment (table 4) is observed that variations, do not exceed the ranges published by different researchers in goats under different feeding regimes (Cantalapiedra-Hijar *et al*., 2009; Paengkoum & Paengkoum, 2010; Wang *et al*., 2009). The effects of treatment, time and interaction treatment by time on ruminal pH values kids observed, indicate that foliage of trees of *P. dulce* Roxb Benth, *G. sepium* Jacq Steud and *H. brasiletto* Karst can include up to 30% of the diet without problems or digestive imbalances. This is because the ruminal pH is an indicator of the balance of the ruminal flora, fermentative processes and end products of digestion of food (Abarghuei et al., 2011; Feng et al., 2013; Ondiek *et al.*, 2013; Paengkoum, 2010; Pérez-Sato *et al*., 2011; Supreena & Peangkoum, 2011).

CONCLUSIONS

Of the study concludes that the density of three trees was low. However, although farmers the used for various services, do not have the culture for projecting an increase in the density of species assessed in live fences systems and rangeland scattered trees. It is concluded that the addition of *P. dulce* Roxb Benth foliage favoured the productive response of the goat kids in weight gain and feed conversion, greater fibre digestibility and ashes as mineralized fraction. The pH was different between animals receiving the foliage of trees *Pithecellobium dulce* Roxb Benth, *Gliricidia sepium* Jacq Steud and *Haematoxilum brasiletto* Karst in the diet, however the observed values never fluctuated outside the ranges established for small ruminants, therefore no digestive disorders were observed affecting eating behaviour, productive performance and health of the animals that destabilized thermoregulatory capacity. The body temperature was different among goat kids because the evaluation hours by the accumulation of environmental temperature caused by solar radiation during the day.

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