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Foraging behaviour and dry matter intake by lambs in a silvopastoral system

Comportamiento de forrajeo y consumo de materia seca por ovinos en un sistema silvopastoril

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ABSTRACT. Dry matter intake, nutritional contribution of forage to the diet and lamb foraging behavior were assessed in a silvopastoral system. Twelve Pelibuey female lambs (6.3 months of age, 23.74 ± 3.5 kg live weight), were randomly assigned to two treatments: pastures of *Digitaria eriantha* (monoculture) or pastures of *D. eriantha* and *Guazuma ulmifolia* (silvopastoral). During a 15 day period, lambs foraged individually in 20.14 m^2 paddocks each day; time spent grazing and browsing were assessed by scan sampling; dry matter intake was estimated (day 11-15), using the chromic oxide (Cr_2O_3) method, and metabolizable energy (ME) and protein (CP) ingested by the lambs were estimated. Data analyses were performed using a complete randomized design (dry matter intake) and a repeated-measure design (ME and CP, foraging time) with factorial treatment structure of season (windy and dry) and pasture (monoculture and silvopastoral). Voluntary intake (season*treatment interaction, p = 0.015) was lower in the windy-silvopastoral treatment (448.5 ± 38.2 g day^{-1}) than in the other treatments (625.8 ± 38.2 to 680.5 ± 38.2 g day^{-1}). The contribution of ME (719.7-1190.2 kcal·day^{-1}) and CP (53.7-100.7 g day^{-1}) was low to cover the lamb requirements in all treatments, because forage availability and dry matter intake were low. Lambs dedicated from 6.65 ± 0.26 to 7.50 ± 0.26 h to foraging; time spent grazing was longer that browsing in the silvopastoral system (p < 0.0001). The time dedicated to foraging, intake, and nutritive quality of forage from in both pasture types did not provide sufficient nutrients and energy during any season for maintenance of the lambs.
Key words: Voluntary intake, tree-grass association, Pelibuey female lambs, energy, and protein consumption, *Guazuma ulmifolia* Lam.

RESUMEN. Se estimó el consumo de materia seca, calidad de dieta y comportamiento forrajero de corderas en un sistema silvopastoril. Se utilizaron 12 corderas Pelibuey (6.3 meses de edad y 23.74 ± 3.5 kg PV), distribuidas en dos tratamientos: pradera de *Digitaria eriantha* (Monocultivo) y asociación *D. eriantha-Guazuma* ulmifolia (Silvopastoril). Durante 15 días, las corderas pastaron individualmente potreros de 20.14 m^2 cada día, se evaluó el tiempo de pastoreo-ramoneo con un muestreo tipo escaneo; se estimó el consumo voluntario de materia seca (días 11-15) con el método oxido de cromo (Cr_2O_3), y cuantificó la energía metabolizable (EM) y proteína (PC) ingeridos diariamente. Se utilizó un modelo completamente aleatorio (consumo de materia seca) y modelos de medidas repetidas (EM y PC, tiempo de forrajeo) con arreglo factorial de época (nortes y seca) y tipo de pastura (monocultivo y silvopastoril). El consumo voluntario difirió (interacción tratamiento*época, p = 0.015), siendo menor en el tratamiento nortes-silvopastoril (448.5 ± 38.2 g $día^{-1}$; p = 0.019) que en los otros tratamientos (625.8 ± 38.2 a 680.5 ± 38.2 g $día^{-1}$). La contribución de EM (719.7-1190.2 Kcal·$día^{-1}$) y PC (53.7-100.7 g $día^{-1}$) a la dieta diaria no cubrió los requerimientos de las ovejas en ningún tratamiento por la baja disponibilidad y consumo de materia seca. Las corderas dedicaron de 6.65 ± 0.26 a 7.50 ± 0.26 h al forrajeo; el tiempo de pastoreo fue más largo que el ramoneo en el sistema silvopastoril (p < 0.0001). El tiempo de forrajeo, consumo y calidad nutritiva del forraje en ningún tratamiento alcanzó a proveer los requerimientos de energía y proteína de las corderas.
Palabras clave: Consumo voluntario, asociación árbol gramínea, ovinos Pelibuey, consumo de energía y proteína, *Guazuma ulmifolia* Lam.

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INTRODUCTION

In tropical regions of the world, the primary forage-base for livestock are grasslands (Boval and Dixon 2012). In these regions, grass growth depends on natural seasonal precipitation that affects forage availability and quality throughout the year, limiting livestock performance and productivity (Giridhar and Samireddypalle 2015). Under proper management, fodder trees contribute to reducing forage shortages because they have phenology and growth habits different than grasses that allow them to grow during drought conditions when grasses become latent (Tamayo-Chim *et al*. 2012, Azuara-Morales *et al*. 2020). Furthermore, fodder trees provide nutrients that complement nutritional needs of grazing livestock (Lara *et al*. 2007). Despite the nutritive quality that fodder trees have, nutritional needs to achieve production goals might not be accomplished, because no forage has a perfect nutrient content to supply all needs for all animals. The nitrogen content of most fodder trees seems enough to sustain growth and high weight gains for meat production systems (Sosa *et al*. 2004, García and Medina 2006, Barros-Rodríguez *et al*. 2012), but it depends on forage availability, nutritional quality of associated forage, dry matter intake and foraging time. The association of *Digitaria eriantha* Steud. cv. Pangola with the tropical tree *Guazuma ulmifolia* Lam. yields a productive silvopastoral system with good quality forage production under tropical conditions (Manríquez-Mendoza *et al*. 2011a, Ortega-Vargas *et al*. 2013), yet, information on the voluntary intake of dry matter, energy and nutrients, or foraging behavior, are not known. This data is particularly important when decisions regarding supplementation needs for small ruminants are needed. The objective of this research was to assess the intake of dry matter, energy, and nutrients as well as foraging behavior of female lambs in an intensive silvopastoral system composed of *D. eriantha* and *G. ulmifolia* during the windy and dry seasons in a tropical climate.

MATERIALS AND METHODS

Experimental site

The experiment was carried out in a region with a sub-humid warm climate classified as Aw1(w)(I')gw" (García 2004), where the mean annual temperature is 26.4 °C and the annual precipitation is less than 1060 mm, with rainfall during summer (June to October).

Seasons and experimental period

This experiment assessed voluntary intake by female lambs during two seasons of the year. The first experimental period (December 27, 2011 to January 10, 2012) took place during the windy season, when the mean ambient air temperature was 26.5 °C, rain was scarce and strong winds occur. The second experimental period (April 12 - 26, 2012) took place during the dry season, when the mean ambient air temperature was 37.1 °C, and air humidity was high. Climatic data was provided by a weather station (Model Pro2™, Davis Instruments, California, USA) at Colegio de Postgraduados, Campus Veracruz (19° 11 44 N; 96° 20 13 W).

Animals and treatments

Twelve Pelibuey female lambs, 6.3 months old and weighing 23.7 ± 3.5 kg were examined. These female lambs were chosen to have similar age and body condition. Each lamb was randomly assigned to one of four treatment groups (n = 6 per group), combinations of season (windy and dry) and pasture type, *D. eriantha* (monoculture) and *D. eriantha* and *G. ulmifolia* (silvopastoral system or SPS).

Paddocks and daily forage supply

Each experimental pasture (monoculture and SPS) was 58 m long and 32 m wide and was divided into fifteen paddocks, one for each day of the experiment. Each day, one of these paddocks was subdivided into six sections (3.8 x 5.3 m equal to 20.14 m^2) to allow one lamb to graze per section in each treatment. Forage allowance was calculated based on a preliminary measure of forage mass performed in the site. Prior to the experiment, the grass and trees were cropped sequentially in each of the 15

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paddocks over a 15-days period to provide 35-days regrowth for each day of the experiment; grass was cut to 10 cm stubble height, and trees were pruned to 1 m in height.

On each day of the experiment, available forage in the monoculture was assessed by cutting the grass to 5 cm above the ground in 10 quadrats (50 x 50 cm) placed systematically along a transect through the pasture section for the day. In the silvopastoral system (SPS), the grass was sampled from six quadrats systematically placed along a transect transverse to the orientation of the tree edge to ensure a more representative sample from full sunlight and shaded areas. Tree fodder was assessed by clipping edible parts from six randomly chosen trees in the same section where the grass was sampled. Edible forage was composed of leaves, non-woody stems, and twigs, simulating herbivory based on observations made in other studies (Manríquez-Mendoza *et al*. 2011b, Ortega-Vargas *et al*. 2013). Fodder available per tree was estimated and then multiplied by the total number of trees in the section for the day; after which total available forage was estimated including grass and tree biomass. Each day, a composite sample was separated from the biomass samples (grass and tree separated) to perform chemical analyses. The samples were oven dried at 60 °C for 48 h, and then ground to 1 mm particle size using a Wiley Mill (Model TS3375E15, Thomas Scientific, New Jersey, USA).

Adaptation period

Before starting the experiment, lambs underwent a 10-day adaptation period to the experimental conditions. During that time, animals foraged from 07:00 to 18:00 h, with free access to water. Those lambs assigned to each treatment foraged together in the same paddock similar to the experimental paddocks.

Experimental procedure

The experimental period was 15-days during both seasons, during which lambs foraged individually in the 20.14 m^2 paddocks previously designed. They stayed in the pastures 24 h per day and were moved to a new section at 09:00 h each day. Dry matter intake (kg DM lamb^{-1} day^{-1}) was assessed using chromic oxide (Cr_2O_3) (Pond *et al*. 1989). Each animal was dosed with 1 g Cr_2O_3 in hard jelly capsules No. 00 (Azteca Brand) at 07:00 h every day and feces were collected from the anus twice a day (08:00 and 14:00 h) during the last five days of the experimental period. At the end, a fecal composite sample was made from these samples for each lamb, from which a subsample was taken, oven dried at 80 °C for 72 h, then ground to a 1 mm particle size using a Wiley Mill (Model TS3375E15, Thomas Scientific, New Jersey, USA).

Chromic oxide in feces was measured using spectrophotometry (Model 80-2097-62, LKB-Ultraspec III Pharmacy, Cambridge, UK) at 440 nm after overnight-dry matter calcination at 450 °C (Fenton and Fenton, 1979). Fecal production (g DM day^{-1}) was estimated using Equation 1, then dry matter intake (voluntary intake) was calculated using the Equation 2 that includes the result from the Equation and the *In vitro* Dry Matter Digestibility (IVDMD) (Ramírez-Pérez *et al*. 2000).

$$fecal\ production\ ((gDM)/day) =$$

$$\frac{Marker\ dose(mg/day)}{Concentration\ marker\ in\ feces\ (mg/(gDM))}$$

$$Voluntary\ Intake\ ((gDM)/day) =$$

$$\frac{Fecal\ production\ ((gDM)/day)}{[1-(IVDMD/100)]}$$

Chemical analyses of the forage samples from the last five days of the experimental periods were performed, and these samples were collected on the same days as the fecal samples. Crude protein was estimated using the macro-Kjeldahl method (AOAC 1980); acid detergent fiber (ADF) and neutral detergent fiber (NDF) were estimated using ANKOM filter bags and the ANKOM^{200} *in vitro* digestion system (ANKOM Technology, New York, USA; ANKOM, 2010); lignin was measured using a 3 L Beaker with 72% H2SO4 and filter bags (AOAC 1997); and IVDMD was determined using ANKOM filter bags and a Daisy^{II} incubator (ANKOM Technology, New York, USA; ANKOM, 2010). Metabolizable energy (ME) was estimated based upon Di Marco (2011):

$$Metabolizable\ energy = 3.61\ x\ IVDMD$$

Time spent foraging (grazing and browsing) was recorded by scan sampling made at five-minute intervals (Solanki 2000). Observations were performed following all the lambs from each treatment in sequence. Each scan observation was converted to five-minute periods of time, then adding the time that each lamb spent performing each activity (Penning and Rutter 2004). Two trained observers performed the observations from 09:00 to 19:00 h. Observations started late in the morning due to Cr_2O_3 dosing, fecal sampling and fencing work that was needed to move lambs to a new paddock every day; observations ended at dusk when visibility was not sufficient to continue.

Statistical analysis

Forage availability, IVDMD, NDF, ADF, metabolizable energy and crude protein (CP) available to the lambs were assessed using descriptive statistics. Dry matter intake was analyzed using a completely randomized design with a factorial treatment structure of season (windy and dry) and two types of pasture (grass monoculture and silvopastoral system) for a total of four treatment combinations: windy-grass, windy-SPS, dry-grass and dry-SPS. The model included the effects of treatment, season, their interaction, and a random error term.

Foraging time, total intake of crude protein and energy were analyzed using a repeated-measure design with a factorial treatment structure of season and types of pasture, the models included the effects of treatment, season, day, all interactions, and a random error term. The model for foraging time used a Compound Symmetry (CS) covariance matrix assuming equal variances on all evaluation dates, and was chosen based on the fitted statistics for the model, while the model for total intake of crude protein and energy used a Toeplitz(1) covariance structure. A paired sample t-test was performed using the *t*-test procedure to test differences in the time spent grazing vs. browsing in the silvopastoral system; a separate test was performed for each season. All analyses were performed using the GLIMMIX procedure and the LSMeans method for mean comparisons in SAS (SAS 2013), except for the t-test.

RESULTS

Forage availability and nutritive quality

Available forage in the 20.14 m^2 assigned to each lamb was 4.16 (grass monoculture) and 2.3 kg DM day^{-1} (silvopastoral) during the windy season, values lower than during the dry season (7.35 for the monoculture and 3.57 kg DM day^{-1} for the silvopastoral system). *Digitaria eriantha* forage had good nutritive quality between seasons, but declined slightly during the dry season, when crude protein decreased, and fiber components increased (Table 1). In the silvopastoral system, grass forage had lower crude protein than the grass monoculture. Tree forage quality was higher than for the grass, having less NDF, ADF and higher CP, while IVDMD was less than for the grass (Table 1).

Dry matter intake

Voluntary intake of dry matter ranged between 1.9 to 3.0% of LW equivalent to intakes from 448 to 680 g day^{-1}. Daily intakes varied as an effect of treatment by season interaction ($p = 0.015$); being greater in the windy-grass, dry-grass and dry-SPS treatments than in the windy-SPS treatment (Table 2).

Foraging behavior

Lambs spent from 6 h 39 min to 7 h 30 min foraging during the day (Table 3), and foraging took place only during the daylight hours (based on observations). There was an effect of day on foraging time ($p < 0.0001$), but not an effect from treatment*day ($p = 0.184$) or season*day ($p = 0.074$); foraging by lambs throughout each day in each treatment depended on season ($p < 0.001$). This interaction denotes a more variable foraging behavior (foraging time) by lambs in the windy-SPS treatment, where foraging was less than in the other treatments during some days of the experimental period. In both seasons, lambs spent

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Table 1. Forage nutritive quality in a *Digitaria eriantha* monoculture and in a silvopastoral system containing *Digitaria eriantha* and *Guazuma ulmifolia* during the windy and dry seasons.

Variable	Grass Monoculture	Silvopastoral System	
	D. eriantha	*D. eriantha*	*G. ulmifolia*
.... Windy			
NDF (%)	64.0 ± 0.02	65.0 ± 0.02	53.0 ± 0.09
ADF (%)	38.0 ± 0.02	40.0 ± 0.02	22.0 ± 0.02
CP (%)	16.1 ± 1.24	10.4 ± 1.51	14.0 ± 1.35
IVDMD (%)	48.0 ± 0.03	46.0 ± 0.02	44.0 ± 0.05
ME (Mcal/kg DM)	1.7 ± 0.12	1.6 ± 0.07	1.6 ± 0.17
.... Dry			
NDF (%)	69.0 ± 0.01	68.0 ± 0.01	45.0 ± 0.02
ADF (%)	41.0 ± 0.01	40.0 ± 0.01	25.0 ± 0.01
CP (%)	8.4 ± 0.83	8.0 ± 0.28	15.2 ± 1.76
IVDMD (%)	50.0 ± 0.02	51.0 ± 0.03	36.0 ± 0.01
ME (Mcal/kg DM)	1.8 ± 0.06	1.8 ± 0.12	1.3 ± 0.05

NDF: Neutral Detergent Fiber, ADF: Acid Detergent Fiber, CP: Crude Protein, IVDMD: *In vitro* Dry Matter Digestibility, ME: Metabolizable Energy.

more time grazing than browsing (p < 0.0001) in the silvopastoral system (Table 3).

Table 2. Dry matter intake by lambs foraging in a grass monoculture (*Digitaria eriantha*) and in a silvopastoral system containing *Digitaria eriantha* and *Guazuma ulmifolia*.

Treatment	g kg^{-1} LW$^{0.75}$	% LW	g day^{-1}
Windy-grass	54.2 ± 3.3^a	2.4^a	625.8 ± 38.2^a
Windy-SPS	41.2 ± 3.3^b	1.9^b	448.5 ± 38.2^b
Dry-grass	59.2 ± 3.3^a	3.0^a	654.4 ± 38.2^a
Dry-SPS	60.2 ± 3.3^a	2.7^a	680.5 ± 38.2^a

Means with different superscript letters within a column are statistically different, α = 0.05; LW: Live weight; numbers after ± are standard errors.

Table 3. Total time spent foraging, grazing, and browsing within a day, by lambs in a grass monoculture (*Digitaria eriantha*) and in a silvopastoral system containing *Digitaria eriantha* and *Guazuma ulmifolia*.

Treatment	Time (h)$^{¥}$	Time 00:00:00 (h:m:s)
Windy-grass	7.50 ± 0.26^a	07:30:00
Windy-SPS	7.46 ± 0.26^a	07:27:06
Dry-gras	7.05 ± 0.26^a	07:03:00
Dry-SPS	6.65 ± 0.26^a	06:39:00
Time grazing vs. browsing in the silvopastoral association$^{¥¥}$		
	Grazing	Browsing
Windy	6.09 ± 0.13^a	1.37 ± 0.13^b
Dry	5.10 ± 0.12^a	1.55 ± 0.12^b

¥ Means with different superscript letters within columns are statistically different, α = 0.05. ¥¥ Comparisons were performed by season; means with different superscript letters within rows are statistically different, α = 0.05; numbers after ± are standard errors.

Pasture energy and nutrient supply

Daily CP ingested by lambs differed among treatments (p < 0.05), being higher in windy-grass (100.7), intermedium in dry-SPS (75.1), and lowest in both dry-grass (56.2) and windy-SPS (53.7) (Table 4). The trees in the silvopastoral treatments provided 50 to 58% of the protein in the diet across seasons (data not shown in Table 4). Similar to the protein supply, lambs obtained more metabolizable energy from the windy-grass, dry-grass and dry-SPS treatments (1190.2 to 1081.2 kcal day^{-1}) than from the windy-SPS treatments (719.7 kcal day^{-1}) (p < 0.05). In the silvopastoral systems, the trees provided 292.4 kcal day^{-1} (40% of daily total supply) during the windy season and 371.9 kcal day^{-1} (33% of daily total supply) during the dry season (data not shown in Table 4).

Table 4. Crude protein and energy supplied by the forage in a grass monoculture (*Digitaria eriantha*) and in a silvopastoral system containing *Digitaria eriantha* and *Guazuma ulmifolia*.

Treatment	Crude Protein (g·d^{-1})	Metabolizable Energy (kcal·d^{-1})
Windy-grass	100.7 ± 4.4^a	1081.2 ± 69.5^a
Windy-SPS	53.7 ± 4.4^c	719.7 ± 69.5^b
Dry-grass	56.2 ± 4.4^c	1190.2 ± 69.5^a
Dry-SPS	75.1 ± 4.4^b	1103.6 ± 69.5^a

DISCUSSION

Lower dry matter availability during the windy season is a plant response to seasonality when they become latent. Low yield has been reported (Manríquez-Mendoza *et al.* 2011b) in the same site during the windy season. The availability of forage in the silvopastoral system was low during both seasons compared with the grass monoculture. Here, pasture management caused variable forage biomass between the pastures because the grass monoculture was a new pasture established immediately prior to starting the experiment in a site that had been at rest for 4 years. Previous accumulation of organic matter favored greater yield in that pasture over the silvopastoral system. The daily forage allowance was enough to fulfill individual lamb dry matter needs, except in the silvopastoral pasture during the windy season, while fodder trees provided a minor proportion, 8.2 (0.188 kg DM) and 7.9% (0.283 kg DM) of total forage biomass during the windy and dry seasons, respectively. This fodder contribution is low for what is needed from trees to complement ruminant diets (Villanueva-Partida *et al.* 2019).

A tendency for declining nutritive quality of grass in the dry season was observed in both the monoculture and the silvopastoral system. In the present research, forage nutritive value in the grass monoculture was high for a grass (Juárez *et al.* 2009), favored because it was a new pasture (Perales *et al.* 2009) established in a nutrient-rich site. Forage quality declined during the dry season as a response to more rapid growth and grass maturity that negatively affected forage quality (Villalobos and Sánchez 2010, Manríquez-Mendoza *et al.* 2011b). Indicators of nutritive quality for the tree are higher than for the grass, but with a lower IVDMD due to the presence of phenolic compounds bound to cell walls and proteins (Carmona 2007). This binding is known to reduce dry matter digestibility (Emmans 1991), but it should not negatively affect dry matter intake or animal performance when concentrations are low (Alves *et al.* 2017, Méndez-Ortiz *et al.* 2018). The nutrient content in *G. ulmifolia* was close to values reported by Pezo *et al.* (1990) and Flores *et al.* (1998).

Dry matter intake was low to normal for the type of animals examined in this experiment, although intakes are lower than those from other reports. For example, Mayren-Mendoza (2018) supplemented lambs (at the same weight and age) with *G. ulmifolia* fodder, and observed a 20% increase in daily dry matter intake when tree fodder was offered at 50% of total DM daily requirements. As a consequence, feed conversion and performance improved. Similarly, crossbred lambs weighing 13 kg ingested from 2.9 to 3.2% LW when fed fodder from five tree species at different supplementation levels (Sosa *et al.* 2004). However, as voluntary intake depends on several internal and external conditions, other authors have reported even higher intakes. González-Garduño *et al.* (2011) recorded from 710 to 790 g DM day^{-1} in lambs of the same age as those in this experiment when fed *Pennisetum purpureum* and other sources of protein. Nahed *et al.* (2011) recorded 868 g DM day^{-1} in creole lambs fed *Buddleia skutchii* fodder as a supplement.

We expected that lambs in the silvopastoral system had greater or similar intakes to those grazing in the monoculture, but this did not occur in our experiment during the windy season. The reason was the lower forage availability in the silvopastoral system during the windy season that was roughly half the amount in the monoculture. Availability of forage directly affects intake (Reinoso and Soto 2006), and the reason for this forage shortage was the climate seasonality that limited availability not only in the silvopastoral system, but also in the monoculture pasture. During the dry season, intakes were higher, and even though less forage was available in the silvopastoral system, lambs made better forage utilization than those in the monoculture.

Greater foraging time during the season of lower forage availability (as in this experiment) and the lower dry matter intake might indicate a smaller bite size (Galli and Cangiano 1998), increasing the time for harvesting food. This situation was more evident in the silvopastoral system where intake was lower during the windy season. Conversely, during the dry season, when there was more forage available in both systems, intake became equal between treatments

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even though total foraging time declined slightly. It is possible, that time spent foraging declined during the dry season due to high temperatures (Forbes 2007), since searching for food was performed during the hotter hours of the day (09:00 to 19:00 h). Prior to this time, when the first feeding bout takes place (Forbes 2007), animals were being manipulated due to experimental procedures. However, they might have compensated for this by feeding during dusk and night hours (Arias *et al*. 2008).

Climate conditions during the dry and windy seasons in the area where this experiment was performed are different (García 2004). During the dry season there is greater solar radiation and higher temperatures, hence the lambs in the silvopastoral system spent more time laying down under large shrubs/trees, protected from the sun rather than foraging (data not shown). However, their intake was equal to those lambs in the grass monoculture, probably due to a higher nutrient content in the forage (Table 1). Lambs in the grass monoculture had little shade to protect them from the sun, thus they spent more time foraging, standing and panting.

Less time browsing suggests low tree fodder availability during both seasons, as was evident during the experiment where fodder was first to disappear from the pastures. Across the experiment, trees contributed no more than 10% of total forage available. Solórzano-Montilla *et al*. (2018) observed West African lambs from 08:00 to 15:00 h in pastures provided with artificial shade during the rainy season and reported that those animals having shade spent more time grazing.

According to our results, if shade is available, animals will spend more time resting, leading to shorter foraging times. Although no comparable reports of this behavior in lambs were found, Kendall *et al*. (2006) observed that dairy cows, when presented with artificial shade, spent the hotter part of the day in the shade, while cows without shade foraged for some time during those hours. As well, Améndola *et al*. (2019) observed heifers had longer foraging times in a grass monoculture than in an intensive silvopastoral system. These reports suggest that available shade in pastures (whether it is in silvopastoral systems or not) promotes resting during the hotter hours of the day to regulate body temperature (Kendall *et al*. 2006, Schütz *et al*. 2009, Améndola *et al*. 2019), apparently reducing foraging time, but this loss may be replaced during other times of the day. Cattle in a monoculture system, however, spent more time searching for food and foraging at times of the day when temperatures were higher, as a compensatory strategy (Améndola *et al*. 2019).

Given the forage available in the paddocks, crude protein supplied by both treatments during both seasons was low, similar to systems based only on grasses as a forage source (Alonso 2011). Thus, the quantity of CP in the diet was below the requirements for this livestock breed, given their weight and physiological state. The growing lambs examined in this experiment should have ingested about 2.4 g kg^{-1} LW$^{0.75}$ day^{-1} for maintenance (INRA 1978). Accordingly, the Agricultural and Food Research Council (AFRC 1993) establishes 75.1 g CP and 2.04 Mcal day^{-1} for a 25 kg LW in order to gain 100 g day^{-1}. Crude protein in the diet was low compared to that in the diet of livestock foraging other pastures having legume trees such as *Leucaena leucocephala*, which can contain up to 30% CP (Dávila *et al*. 1997, Sosa *et al*. 2004). In comparison, *G. ulmifolia* as a non-leguminous tree, contains up to 18-20% CP (Manríquez-Mendoza *et al*. 2011a, Ortega-Vargas *et al*. 2013). Energy supply also was low in both treatments and seasons compared to that recommended by Chay-Canul *et al*. (2016) for Pelibuey lambs (2.0 Mcal day^{-1}) weighing 25 kg LW and gaining 50 g day^{-1}. Thus, fodder tree dry matter offered in this silvopastoral system would have to increase to a higher nutrient supply, or a supplementation strategy must be considered. Forage nutritive value was assessed from samples clipped 5 cm above the ground, but the nutrient content of these samples might differ from the actual nutrient intake because sheep are selective and might have chosen more digestible forage (Caja 2001). Given the low availability of forage, it is likely that true energy and nutrient intake differed from that estimated for the examined samples.

CONCLUSIONS

Given the limitations on forage availability, voluntary intake in the silvopastoral system with *D. eriantha* and *G. ulmifolia* was low and depended on season. Intake was higher during the dry season when forage availability increased, and less time was spent foraging. Energy and crude protein supply also were restrictive, but given the nutritious quality of the tree fodder, this restriction might be overcome by increasing forage allowance during times of forage shortage by increasing tree density in pastures to increase fodder and nutrient supply in the system.

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