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Article

Productive and ingestive behavior in growing hair sheep in silvopastoral and stabled weight-gain systems

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Abstract:
In sheep silvopastoral systems, forage legumes are promising alternatives to commercial feed since they can lower costs. An evaluation was done comparing productive and ingestive behavior parameters in hair sheep in silvopastoral and stabled systems for four months. Nine variables were evaluated: dry matter intake (DMI); organic matter intake (OMI); crude protein intake (CPI); neutral detergent fiber intake (NDFI); daily weight gain (DWG); feeding time (FT); rumination (RT); walking (WT); and other activities time (OAT). Experimental animals were eighteen sheep (initial weight= 16.83 x 2.57 kg) distributed in a completely random design, with three treatments: a silvopastoral system (SPS) including the

legume *Leucaena leucocephala* and the grass *Cynodon plectostachyus* (L+E); another SPS including *L. leucocephala* and the grass *Panicum maximum* (L+M); and a stabled weight-gain system (SWS). Orthogonal contrasts were applied to compare the SWS *vs* SPSs and the two SPSs. Compared to the two SPSs, all intakes (DMI= 1246.2 g; OMI= 1073.0 g; CPI= 157.1 g; and NDFI= 364.0 g animal d^{-1}) and DWG (195 g animal d^{-1}) were higher (P<0.001) in the SWS. Daily weight gain did not differ between the SPSs (102 and 114 g animal d^{-1}), but all intakes were higher (P<0.001) in L+M (DMI= 772.2 g; OMI= 662.7 g; CPI= 124.0 g; and NDFI= 334.2 g animal d^{-1}) than in L+E (DMI= 548.9 g; OMI= 86.20 g; CPI= 483.0 g; NDFI= 252.3 g animal d^{-1}). Feeding time (FT) was shortest (P<0.001) in the SWS (148.33 min). Between the SPSs, FT was shortest (P<0.05) in the L+E (318.3 min) than in the L+M (344.6 min). Time dedicated to other activities was longer (P<0.001) in the SWS (247.9 min) than in the SPSs. Silvopastoral systems combining legumes and grasses provided sufficient growth in hair sheep although the stabled weight gain system produced faster growth in the studied time period.

Key words: Grazing, stabled, productive and ingestive parameters.

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Introduction

Sheep production in the tropics of Mexico has been growing in response to increasing demand and attractive market prices. However, productivity in grazing sheep is limited mainly by low pasture availability and quality during the dry season. This affects lamb growth and development and consequently the time required for finishing animals for sale(1).

An alternative for addressing problems of low fodder availability and quality is the use of forage trees and shrubs which have higher nitrogen content than grasses, a compound that promotes proper rumen functioning(2). Forage trees and shrubs are also an excellent source of digestible energy and can provide bypass protein, which is required to ensure a productive response in grazing animals under tropical conditions(3).

Integration of forage trees and bushes into sheep production systems in the tropics has grown as silvopastoral systems (SPSs) are implemented as an alternative in livestock production. These systems associate trees and shrubs with traditional elements (i.e. grasses and animals) within a comprehensive management system that provides high fodder availability and quality for animal feed year-round as well as providing environmental benefits(4). However, it is important to understand sheep ingestive behavior in these systems. For example, animals with limited grazing in SPS use most of their time for feeding, with minimal time dedicated to walking or extended rest and ruminating periods[5].

Most studies show positive effects on voluntary intake and animal weight gain when controlled quantities of forage tree species are included in diets[6,7]. However, these studies have been done under controlled conditions with stabled animals and may not express the actual potential of forage tree species since grazing animals have greater energy expenditure, which may limit maximum productive expression of this feed alternative[2].

The leguminous forage tree *Leucaena leucocephala* has been widely studied and is commonly used for establishing SPS in the tropics. In Mexico little is known about this legume's potential when used in SPS and how it affects weight gain in ruminants[8] in comparison to stabled conditions. More knowledge is needed on the use of alternative forage plants to replace commercial feeds, which increase production costs. Although SPSs have been extensively studied in other countries, in southeast Mexico further evaluation is needed of these systems when animals are directly involved in the system through grazing, and to assess if their use is feasible for weight gain and finishing of animals intended for market. The present study objective was to evaluate productive and ingestive parameters in hair sheep grazing two SPSs based on *L. leucocephala* and compare them to a stabled weight gain system (SWS).

Material and methods

Study area

The study was done at the Instituto Tecnológico de la Zona Maya (18°31' N; 88° 29' W), in the state of Quintana Roo, Mexico. Regional climate is warm sub-humid (Aw_1), with annual mean temperatures ranging from 24.5 to 25.8 °C[9]. Based on the IUSS classification system, soils are predominantly haplic greysols[10]. The study was done during the rainy season, from September to December 2016.

Animals, handling and feeding

Experimental animals were 18 males (Pelibuey × Blackbelly) with a 16.83 ± 2.57 kg initial weight. These were randomly divided into three groups of six animals each, corresponding to three treatments. The animals were weighed at the beginning of the trial and deparasitized with 1% ivermectin at 1 ml / 50 kg live weight (LW) (Iverfull®, ArandaLab®) and 5% closantel at 1 ml / 10 kg LW (Closantel-Panavet® 5%). They were administered two vitamin supplements: 2 ml per animal of a multivitamin containing retinol (Vit. A), colecalcipherol (Vit. D3) and tocopherol acetate (Vit. E) (Vigantol ADE-Bayer); and 5 ml per animal of a B complex (Complejo-B, Virbac). They were allowed 15 d adaptation before the treatments were begun. Disease treatment was done following established national animal welfare and health guidelines (NOM-062-ZOO-1999).

Three treatments were evaluated: SWS, based on a commercial feed concentrate and fresh grass; L+E, based on *L. leucocephala* and *Cynodom plectostachyus*; and L+M, based on *L. leucocephala* and *Panicum maximum*.

Evaluated variables

Nine variables were evaluated. Five were productive variables (g animal^{-1} d^{-1}): daily weight gain (g animal^{-1} d^{-1}; DWG); dry matter intake (DMI); crude protein intake (CPI); organic matter intake (OMI); and neutral detergent fiber intake (g animal^{-1} d^{-1}; NDFI). Another four addressed ingestive behavior (minutes): feeding time (FT); ruminating time (RT); walking time (WT); and other activities time (OAT).

Available forage estimation

Before the grazing treatments, random samples were collected of forage in each area following an established technique[11]. Briefly, a one square-meter frame was placed over an area containing grass and this cut to 10 to 15 cm above soil surface, approximating the height at which the animals were observed to graze it. *Leucaena leucocephala* was cut at 40 cm above soil surface. Samples were weighed fresh. A subsample was dried in a forced air stove for 72 h at 60 °C to constant weight and weighed. These data were used to calculate dry matter content per hectare. All the samples were ground for later chemical composition analyses.

Pens and feeding

In the SWS, animals were housed in individual pens divided by sheep fencing in a building with concrete walls and floors, and a sheet metal roof. Each pen was equipped with feeders and water bottles, and feed and water were freely available. The commercial feed (Maltacleyton Premium) was adjusted according to production stage (15% CP in months 1 and 2, and 13% CP in months 3 and 4). Chopped fresh grass (*P. maximum* cv. Mombaza) was provided separately. Throughout the experimental period the feed ratio was 70 % feed concentrate and 30 % grass.

In the SPSs the animals were grazed in pastures containing 36,000 *L. leucocephala* plants with grass between the rows. These plots were established in 2014 under seasonal conditions and without application of fertilizers. Electric fence was used to divide each SPS pasture (1 ha) into four 2,500 m^2 paddocks. These were trimmed every 60 d at a height of 40 cm for *L. leucocephala* and 10 to 20 cm for the associated grasses. The daily area used per animal lot inside the paddocks averaged 178 ± 29.54 m^2. This was calculated based on average dry matter intake (DMI) per animal (3 to 4.5 % LW) and adjusted every fourteen days. Rotational grazing was used with polywire fence from 0700 to 1600 h; a container of clean water was provided during this time. After grazing the animals were stabled in individual pens like those used in the SWS treatment, where they were provided with a portion equivalent to 20 % commercial feed concentrate based on the quantity offered animals in the SWS (70 % of total diet). Grazing time and feed in all three treatments were adjusted every 14 d.

Voluntary intake (VI)

Voluntary intake (VI) in the SWS was determined using the difference between the feed offered and that rejected during 24 h. Values for DMI, OMI, CPI and NDFI were estimated using VI and the chemical composition of the feed concentrate and grass.

In the SPSs, VI was estimated individually with the external marker technique[12], using chromium oxide (Cr_2O_3) as a marker. This was administered the animals for eleven days during the second and fourth months of testing. Stool samples were collected directly from the rectum over three days, dried in a forced air stove at 60 °C to constant weight, and ground.

Daily weight gain (DWG)

Daily weight gain was measured by weighing animals on a digital scale, after a 15-hour fast, at 0, 14, 28, 42, 56, 75, 84, 98, 112 and 140 d. Weight was measured before feeding, and DWG estimated as the slope of the linear regression between VI and days.

Ingestive behavior

The activities involved in ingestive behavior were documented following an established methodology[13] in which three sheep were randomly selected per treatment and one observer assigned each animal. Animal activities were recorded every 5 min during a 9-hour period (equivalent to grazing time) over four consecutive days every month from October to December. The total time allotted each activity by the animal was calculated based on behavioral activity times in five-minute intervals.

Laboratory analysis and calculations

Samples were taken of the commercial feed, grasses, legumes and weeds eaten by the animals to measure DM, OM and CP contents with AOAC techniques[14], while NDF content was measured according to Van Soest *et al*[15].

Feces Cr_2O_3 content was measured with a microwave plasma atomic emission spectroscope (MP-AES 4200, Agilent) coupled to a nitrogen generator (Genius 5200, Peak). *In vitro* dry matter digestibility (IVDMD) was quantified in forage samples from each SPS[16]. Feces production and DMI were estimated using published formulas[17], and adding DMI corresponding to the feed concentrate provided in the pens:

$$Feces\ Prod.(g\ DM/day) = \frac{Marker\ Dose\ (mg/day)}{Marker\ concentration\ in\ feces\ (mg/g\ DM)}$$

$$Voluntary\ intake\ (g/day) = \frac{Feces\ production\ (g\ DM/day)}{[1 - (IVDMD/100)]}$$

Estimates of DMI, CPI, OMI, and NDFI were made using VI values and chemical composition for the grasses, weeds, *L. leucocephala* and feed concentrate.

Experimental design and statistical analysis

Response variables were compared with an orthogonal contrast test in a completely random design with three treatments and six replicates. Calculation of differences between SWS *vs* L+E and L+M, as well as L+E *vs* L+M were done with the PROC GLM in the SAS statistics program(18).

Results and discussion

Forage availability and chemical composition

The L+M system provided more (*P*<0.05) dry matter than the L+E system, which is unexpected since *C. plectostachyus* had higher DM, NDF and OM contents than *P. maximum*.

Table 1: Chemical composition of forage species and feed concentrate, and forage availability in the silvopastoral systems.

Content	*L. leucocephala*	*C. plectostachyus*	*P. maximum*	Feed concentrate
DM, %	25.08 ± 3.71	28.5 ± 5.52	21.30 ± 3.96	89.05 ± 2.70
CP, %	21.38 ± 1.17	8.21 ± 1.68	8.36 ± 1.38	13.33 ± 0.43
NDF, %	37.58 ± 1.97	57.50 ± 1.31	55.15 ± 1.88	12.25 ± 0.75
OM, %	86.46 ± 0.92	89.37 ± 0.49	84.42 ± 1.24	85.51 ± 0.11
Forage availability (t DM ha^{-1}):				
System				Total
L+E	3.56 ± 0.71	3.73 ± 0.77		7.30 ± 1.49 ^{b}
L+M	2.01 ±0.19		8.64 ±0.09	10.65 ±0.28 ^{a}
P value				0.012

L+E = *Leucaena leucocephala* + *Cynodon plectostachyus*; L+M = *Leucaena leucocephala* + *Panicum maximum*.

^{ab} Different letter superscripts in the same column indicate significant difference (*P*<0.05).

Weight gain

Daily weight gain (DWG) was higher in the SWS (P<0.001) than in the SPSs, which did not differ (P>0.05). Animals in the SWS had higher DMI, PCI, OMI and NDFI (P<0.001), than in the SPSs, and those in the L+M had higher values (P<0.001) than those in the L+E (Table 2).

Table 2: Daily weight gain and nutrient intake in hair sheep in a stabled weight gain system (SWS) and two silvopastoral systems (g animal^{-1}d^{-1})

	Treatments				Contrasts	
Parameters	**SWS**	**L+E**	**L+M**	**SE**	**Cont. 1**	**Cont. 2**
DWG	195	102	114	8.7	**	NS
DMI	1246.2	548.9	772.2	22.6	**	**
CPI	157.1	86.2	124.0	3.4	**	**
OMI	1073.0	483.0	662.7	19.7	**	**
NDFI	364.0	252.3	334.2	11.5	**	**

DWG = daily weight gain; DMI = dry matter intake; CPI = crude protein intake; OMI = organic matter intake; NDFI = neutral detergent fiber intake; Cont. 1 = SWS *vs.* SPSs; Cont. 2 = L+E *vs.* L+M; SE = standard error between means.
**= P<0.001; NS= P>0.05.

The higher DWG in the SWS was associated with the increased DMI, PCI, OMI and NDFI in this treatment. Similar results have been reported in sheep fed diets containing high proportions of concentrate (14% CP and 8.36 MJ/kg DM) in which higher concentrate consumption may have led to greater DM ruminal degradability and ruminal flow rate, and consequently more weight gain(19). In another study the production parameters in goats fed diets supplemented with peanut cake were directly linked to nutrient intake which influences dietary fiber digestibility and weight gain during growth(20), similar to the present results.

The lack of significant difference in DWG between L+E and L+M may indicate that the higher DMI (223.24 g animal^{-1} d^{-1}), OMI (179.66 g animal^{-1} d^{-1}) and CPI (37.80 g animal^{-1} d^{-1}) values in L+M were insufficient to digest the higher NDFI (81.94 g animal^{-1} d^{-1}) present in both SPSs. This coincides with a previous report suggesting that consumption of higher amounts of cellulose and lignin in ruminants fed tropical grasses and legumes reduced forage transit rate, leading to longer rumen retention times, and consequently modifying DWG(21).

In the SWS, the DWG values (195 g animal^{-1} d^{-1}) were slightly higher than those reported for sheep fed different proportions of grain silage (maize, sorghum and millet) plus 50 % commercial feed concentrate (120 to 180 g animal^{-1} d^{-1})(22). In contrast, the DWG values for L+E (102 g animal^{-1} d^{-1}) and L+M (114 g animal^{-1} d^{-1}) were similar to those reported for hair sheep grazed in a SPS containing *L. leucocephala* (35,000 plants/ha) and *P. maximum* (106 g animal^{-1} d^{-1})[23]. Weight gain in the two studied SPSs was within DWG ranges reported for lambs fed feed concentrate plus the grass *Pennisetum purpureum* plus 30 % inclusion of the forage trees *Moringa oleifera* or *Trichanthera gigantea* (96 to 155 g animal^{-1} d^{-1})[24], and for sheep fed the grass *C. plectostachyus* and different inclusion levels of the forage trees *Guázuma ulmifolia*, *L. leucocephala* or *Gliricidia sepium* (54 to 137 g animal^{-1} d^{-1})[25].

Intake values in the SWS (DMI, 1,246.24 g; CPI, 157.11 g; OMI, 1073.03 g; and NDFI, 363.99 g animal^{-1} d^{-1}) are near those for growing Pelibuey lambs fed the grass *Cenchrusaris ciliaris* Link. and a conventional concentrate including exogenous enzymes (DMI, 1029 to 1120 g; OMI 928 to 976 g; CPI 130 to 137 g; NDFI 447 to 470 g animal^{-1} d^{-1})[26].

One aspect to consider in the present study is that the animals were allowed to graze for nine hours. Given the season, forage intake can decline between 1100 and 1400 h due to extreme heat, which may have contributed to reducing intake and thus lowering DWG in the SPS treatments. Moreover, feeding of 20 % concentrate in the pens after grazing may have conditioned the animals to wait for this ration, consequently decreasing their feeding time and intake on the pasture.

Feeding behavior

Animals in the SWS spent less time feeding than those in the SPSs (P<0.001). In addition, animals in the L+E spent less time feeding than those in the L+M (P<0.05). Time spent walking (WT) and ruminating (RT) did not differ between the SWS and the SPSs (P>0.05). This is of note since the SWS included less fiber in the diet and would be expected to have had a shorter RT than in the SPSs. Perhaps this is due to the animals in the SPSs choosing young grass and legume leaves, which would lower their fiber intake and result in similar rumination times in the three studied systems. Other activities (OAT) occupied a greater portion of the time in the SWS than in the SPSs (P<0.01), although OAT values did not differ between L+E and L+M (P>0.05) (Table 3).

Table 3: Ingestive behavior in the stabled weight gain system and two silvopastoral systems based on *L. leucocephala* and associated grasses

	Treatments				Contrasts	
Activity	**SWS**	**L+E**	**L+M**	**SE**	**Cont. 1**	**Cont. 2**
Feeding time, min	148.33	318.33	344.58	8.28	**	*
Walking time, min	20.00	24.17	30.00	7.25	NS	NS
Ruminating time, min	62.08	53.75	31.67	10.33	NS	NS
Other activities, min	247.92	83.75	73.75	12.90	**	NS

SWS = stabled weight gain system; L+E = *Leucaena leucocephala* + *Cynodon plectostachyus*; L+M = *Leucaena leucocephala* + *Panicum maximum*; SE= standard error between means;
Cont. 1 = SWS *vs.* SPSs; Cont. 2 = L+E *vs.* L+M.
*= P<0.05; **= P<0.001; NS= P>0.05.

Feeding times (FT) in the present results were higher than those reported in sheep fed ammoniated *C. ciliaris* L. in which this variable accounted for 38.4 % of daily activities(27); these differences are probably due to use of a 9 h daily observation period in the present study compared to a 24-h period in the previous study. However, the present results are similar to those reported for other ruminants (bovines) in a restricted grazing regime including *Bracharia humidicola* and *P. maximum* infested with legume creepers(28), and another regime involving *Cynodon nlemfuensis* supplemented with corn distillers grains in the dry season(29).

The present ingestive behavior results also coincide with those reported for goats in an SPS using *P. maximum*, *L. leucocephala*, native legumes and natural pastures(5), in which the animals spent most of their time walking and feeding (152 min and 36.28 % during 8 h observation). In another study goat kids grazing *C. nlemfuensis* were found to prefer grazing pasture in the daytime, spending from 82 to 83 % of their time doing it(30). The fact that FT in the present results was shortest (15.44 min) and least frequent (31.34 %) in the SWS treatment may be associated with several factors such as feed supplementation. This has been reported elsewhere in ruminants grazing *C. nlemfuensis* supplemented with 1.5 or 2.5 kg corn distillers grains in which feeding time was shorter and thus allowed more time for other activities or resting(29).

Differences in FT between the SWS and the SPSs, as well as between the two SPS treatments, may be due to variations in diet NDF content. For example, in a report on sheep fed ammoniated *C. ciliaris* L. hay higher dietary fiber content was related to longer rumination time, suggesting that the time spent on feeding and ruminating was influenced by diet composition and was probably proportional to cell wall content(27). This does not coincide with the rumination times and frequencies in the SPSs studied here which had shorter rumination times and frequencies than previous reports(26); worth noting is that after grazing the animals did engage in rumination once penned. However, the previous results are similar to the rumination time and frequency in the SWS, perhaps due to lower grass (and therefore fiber) content in the diet.

More research is needed to corroborate hair sheep productive and ingestive behavior year-round. The number of observations used in the present study was limited due to the difficulty of observation during the rainy season. Despite some limitations, the present results provide an encouraging picture of the use of silvopastoral systems in sheep production in southern Quintana Roo.

Conclusions and implications

Hair sheep in the stabled weight-gain system exhibited greater weight gain than the silvopastoral systems due to higher dry matter, crude protein, organic matter and neutral detergent fiber intake, and they required less time to feed. Weight gain in the two tested silvopastoral systems did not differ despite higher intake levels in the *L. leucocephala*-Mombaza grass association, probably due to longer feeding time. Walking and ruminating times did not differ between the three production systems. Silvopastoral systems are promising alternative production systems in the tropics because they incorporate tree legumes such as *L. leucocephala*. These are rich in nutrients, particularly protein, and promote higher feed intake in ruminants consequently increasing livestock production under grazing conditions and reducing dependence on external inputs.

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