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Article

Erythrina americana Miller foliage intake in Blackbelly x Pelibuey ewes

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Abstract:

Legume tree foliage can be used as a supplement to grasses in some livestock species. A study was done of the influence that live weight category (LWC) in Blackbelly x Pelibuey ewes has on voluntary intake and digestibility of *Erythrina americana* foliage, productive efficiency, changes in blood variables and in the number of gastrointestinal nematode eggs per gram feces (EGF). The experimental design was completely random. The factors were

LWC (light: 22.2 kg, heavy: 34.4 kg) and evaluation period (EP). Evaluated variables included live weight (LW), daily weight gain (DWG), *in situ* dry matter degradability (IDMD), daily dry matter intake (g kg^{-1} LW), crude protein (CP; g kg^{-1} LW), structural carbohydrates (SC; %), metabolizable energy (ME; Mcal kg^{-1} LW), condensed tannins (CT; g kg^{-1} BW) and EGF. Both LWC and EP affected (P<0.01) nutrient intake. The light LWC exhibited a higher nutrient and CT intake (P<0.01) than the heavy LWC, although without a commensurate increase in DWG. The blood variables and EGF were unaffected (P>0.05) by the studied factors and their interaction. *Erythrina americana* foliage CP, SC and CT contents suggest that it can be used as a sole feed source for short periods (less than 28 days). In both live weight categories *E. americana* intake produced a positive evolution in DWG and did not affect health status.

Key words: Agroforestry trees, Intake, Hair sheep, Humid tropics.

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Introduction

The foliage of tree legumes contains a higher crude protein (CP) concentration than do creeping and bunch type tropical grasses[1]. Incorporating tree legumes into sheep grazing systems is therefore recommended as a complementary CP source[2]. For multiple reasons use of tree legume foliage in small ruminant feed systems is infrequent. Primary among them being a lack of knowledge of the presence and concentration of secondary compounds and the levels at which they can be included in sheep diets without affecting productive efficiency and animal health condition[3].

Among forage tree legumes, the genus *Erythrina* stands outs because of its distribution in the tropics and subtropics, which facilitates acquisition of vegetative material for establishment and propagation[4,5]. Coral tree *Erythrina americana* is widely used as a live fence on livestock farms in tropical regions, making it readily available for harvesting foliage for small ruminant feed[6,7]. During the dry season, cattle in the tropics, mainly lactating cows and calves, are fed *Erythrina* foliage as a feed supplement. Foliage is collected from trees in pastures and live fences, and in some cases from cultivated orchards. It is freely supplied to animals as cut branches and as foliage in feed troughs[8].

Studies of *Erythrina* inclusion in sheep diets have proven inconclusive. Some indicate that *Erythrina* foliage is easily consumed at up to 30 % inclusion[9,10], others report negative daily weight gain (DWG) (-20 g animal^{-1}) at a 50 % inclusion level, and still others report a positive DWG (74 g animal^{-1}) when *Erythrina* foliage is the sole feed[11,12]. However, there is limited information on the productive behavior and health condition of sheep when fed *E. americana* foliage as the sole feed source[11], a promising option during short environmental contingencies (e.g. droughts).

Previous studies of *E. goldmanii* indicate its foliage contains condensed tannins (CT)[9]. No data is available to date on CT concentration in foliage from unpruned *E. americana* (very common in live fences), nor is their information on the CT intake tolerated in sheep when *E. americana* is the sole feed source[13]. Understanding CT tolerance levels is vital because at concentrations greater than 50 g kg^{-1} dry matter (DM) this type of plant secondary metabolite can bind and precipitate soluble proteins and carbohydrates, negatively affecting DM degradability[14]. However, consumption of CT-containing foliage can help control gastrointestinal nematodes in livestock[15]. The present study objective was to quantify the influence of live weight category (LWC) in Blackbelly x Pelibuey sheep on voluntary intake and digestibility of *E. americana* foliage, productive performance, blood variables and gastrointestinal nematode egg counts in feces.

Material and methods

Study area and housing

The study was done at the sheep experimental unit of the National Institute of Forestry, Agricultural and Livestock Research (Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias - INIFAP), in Huimanguillo, Tabasco, Mexico (17°50' N, 93°23' W). Regional climate is warm humid with year-round rains [Af (m)] and a 27.8 °C average annual temperature[16]. During the study period, minimum and maximum temperature was measured daily at 0800 h (24 hours) with a Six's type thermometer. Weekly and general averages were calculated from this data: average minimum temperature was 23.0 ± 1.1 and average maximum was 35.5 ± 2.1 °C. The *E. americana* foliage was fed to sheep in individual pens with a 2.4 m^2 area, a concrete floor, drinker, feed trough and asbestos sheet roof.

Animal handling

Experimental animals were nine non-gestating, non-lactating Blackbelly x Pelibuey ewes distributed into two groups based on live weight category (LWC) and age. Four animals of two years of age were included in the light LWC (22.2 ± 1.2 kg LW), while five animals of three years of age were included in the heavy LWC (34.4 ± 1.1 kg LW). Prior to beginning the experiment each animal was injected with 1 ml ADE vitamins (Vigantol Bayer®) (500,000 IU vitamin A, 75,000 IU vitamin D, 50 mg vitamin E per ml). Animal management practices complied with established institutional guidelines (Reglamento para el Uso y Cuidado de Animales Destinados a la Investigación en el Colegio de Postgraduados, CP-02.11.16).

The experimental period was 42 days, including 14 d of adaptation to the diet and 28 d for the feeding trial. Initially, all the sheep were allowed to graze *Cynodon plectostachyus* pasture from 0800 to 1300 h after which each group was placed in a pen with free access to *E. americana* foliage (300 g sheep^{-1} d^{-1}), water and mineral salts (Magnophoscal®, phosphorus 17.5 g; calcium 6.5 g; sodium 10.5 g; magnesium 4.5 g; sulfur 2.0 g). The grazing period was gradually reduced at a rate of one hour every two days until the sheep spent all day in the pen. The amount of *E. americana* foliage provided was increased by 100 g sheep^{-1} day^{-1} until it became the sole feed source. During the 28-day feeding trial each animal was housed in an individual pen and provided free access to water and *E. americana* foliage from 0800 to 1800 h, supplied at a rate that resulted in at least 10% rejected feed. When the feeding trial ended all the light LWC sheep were housed in one pen and all the heavy LWC sheep in another. They were kept there overnight for safety, with free access to water and mineral salts.

Collection and chemical analysis of *E. americana* foliage

Foliage (leaves and petioles) collection was done during the late northwinds season and early dry season (February-March 2017). Collections were taken from trees with no history of pruning and which formed part of live fences marking sheep pastures. Pruning shears and a machete were used to remove branches and the foliage then removed from them. The collected foliage was dried by spreading in layers no thicker than 3 cm on a concrete floor under a roof at room temperature (28.2 ± 1.3 °C) for 72 h. It was turned over and mixed twice daily to improve drying.

Evaluated variables

Data on chemical composition of and secondary metabolites in the foliage of *E. americana* was collected from foliage samples taken every week during the experimental period. Duplicate analyses were done of dry matter content (DM); ash; organic matter (OM) and crude protein (CP) using AOAC methods[17]. Other techniques were used to quantify neutral detergent fiber (NDF) and acid detergent fiber (ADF)[18]; *in situ* DM degradation (IDMD)[19], metabolizable energy (ME, Mcal kg^{-1} DM)[20], total polyphenols (g kg^{-1} DM), non-tannin phenols (g kg^{-1} DM)[21], condensed tannins (CT; g kg^{-1} DM), hydrolysable tannins (g kg^{-1} DM) and total tannins (g kg^{-1} DM)[22,23,24].

The nylon bag technique used to quantify foliage IDMD[19], was implemented with three male cattle (*Bos indicus* x *Bos taurus*)(average LW = 500 ± 20 kg), that had been castrated and fitted with a rumen cannula. They were grazed in a pasture containing predominantly white gramalote grass (*Paspalum fasciculatum*) which provided 22.04 % DM, 6.73 % CP, 78.55 % NDF and 53.8 % ADF. This was supplemented with 2 kg of feed consisting of 70 % chickpea, 20 % rice polish and 10 % molasses (83.87% DM, 20.80 % CP, 28.43 % NDF and 7.42 % ADF). For the IDMD trial 5 g dry and ground *E. americana* foliage (Thomas-Willey mill, model 4 Laboratory Mill) was incubated in each rumen cannula with a 2 mm sieve, in polysilk bags (10 x 20 cm, 45µm porosity), in duplicate for 24 h. The bags were removed, washed with running water, and dried in a forced air oven at 105 °C for 72 h. Dry matter degradation was calculated with the formula: (g initial DM - g residual DM) / (g initial DM) X 100.

Changes in live weight (LW) were quantified by weighing the sheep on two consecutive days at 14-d intervals during the feeding trial. A platform scale (Oken®) was used with 200 g accuracy.

Daily weight gain (DWG) was calculated by the difference of final weight minus initial weight divided by the number of days in the experimental period. Foliage offered and rejected was weighed per pen weekly over three consecutive days.
Weekly intake per pen was calculated by subtracting the quantity offered and that rejected. The foliage consumption index (%) was calculated at seven-day intervals for four periods by multiplying total DM intake by 100 and dividing by animal LW.

Mineral salt intake was measured by weighing the salt offered and rejected per pen weekly over three consecutive days. Weekly intake per pen was calculated by subtracting the quantity offered and that rejected.

Crude protein (CP), metabolizable energy (ME) and condensed tannins (CT) intake were calculated by multiplying total DM intake by foliage nutrient content and dividing by 100. Body condition (BC) was calculated at 14-day intervals during the feeding trial using a one-to-five scale[25].

FAMACHA© monitoring was done based on ocular mucosa color as determined by the five-point FAMACHA© card color scale[26]; intense red corresponds to a value of 1 (healthy) while white corresponds to a value of 5 (anemia = heavily infected). This evaluation was performed by the same person at the beginning and end of the feeding trial.

Blood variables were measured by taking blood samples with the jugular vein puncture technique and collecting the blood in 4 ml vacutainer tubes containing EDTA. Blood collection was done at 0800 h on days 1 (beginning) 14 and 28 of the feeding trial. Blood samples were transferred to the laboratory for analysis in an automated hematology device (Medonic CA 620/530). The components analyzed included red blood cells ($x10^{12}$ L), hemoglobin (g dl^{-1}), hematocrit (%), mean red blood cell corpuscular volume (x 10^{15} L), white blood cells (x 10^{9} L), lymphocytes (x 10^{9} L) and granulocytes (x 10^{9} L).

Gastrointestinal nematode egg counts were done be taking fecal samples from each sheep at 0700 h at 14-day intervals throughout the experimental period. Each sample was collected directly from the rectum of each animal using a plastic bag and 2 g processed with the McMaster technique to determine egg count per gram of feces (EGF)[27].

Experimental design and statistical analysis

During the feeding trial (28 d) measurements were taken of the same animals at 7- and 14-d intervals, therefore evaluation period (EP) was considered an independent variable. An experimental two-factor design was used with repeated measures in one factor[28]. The first factor was sheep LWC (light and heavy). The second factor was the EP (two 14-d periods to evaluate changes in LW, and four 7-d periods to evaluate changes in nutrient intake). The experimental unit was one sheep.

Statistical analyzes were done with the SAS statistical package[29]. Descriptive statistics (mean ± standard deviation) were used to describe the values of *E. americana* foliage chemical composition, IDMD, DM, phenols and their fractions, as well as daily mineral salt intake. The Shapiro-Wilk test was applied to the remaining data to verify normal data distribution and the Levene test to confirm variance homogeneity. The EGF results were transformed with the natural logarithm (Log EGF +1) to provide them a normal distribution.

The experimental unit was one sheep. Statistical analyzes of LW and total DWG were run with the GLM PROC. The PROC MIXED[30] was applied to identify the influence of EP, LWC and their interaction on DM, CP, ME and CT intakes, DWG, IDMD, EGF, and the blood variables. The means were compared with a Student t test and least mean squares using the pdiff option in SAS. The body condition (BC) and FAMACHA variables were analyzed with the Wilcoxon rank sum test for unpaired data[31].

Results and discussion

The *E. americana* foliage results for chemical composition, IDMD, DM, phenols and their fractions showed it to be generally within reported ranges, although structural carbohydrates were higher than in previous studies (Table 1). The 18.9 % average CP value in the present results was within the 14.5 to 25.6 % range reported for *E. americana* foliage from a humid tropical region in the state of Tabasco, Mexico[2,32]. The IDMD result (42.7 %) was also similar to the 42.7 % reported for *E. americana* foliage harvested during the dry season[32]. However, structural carbohydrates content (71.6 % NDF, 56.7 % ADF) was higher than reported elsewhere (52.4% NDF, 40.1% ADF)[2]. Increases in structural carbohydrates content is commonly associated with greater plant age. This coincides with the present study in which the foliage was harvested in the early spring when *E. americana* in the study area bloom and a significant proportion of leaves are mature[4]; this would explain the high structural carbohydrate content, and low IDMD and DM values.

Table 1: Chemical composition, *in situ* dry matter degradability (IDMD), metabolizable energy (ME), phenols and their fractions in *Erythrina americana* foliage

Component	Number of components	Mean ± SD
Dry matter (DM), %	4	84.9 ± 7.3
Organic matter , %	4	90.2 ± 0.3
Crude protein , %	4	18.9 ± 1.8
Neutral detergent fiber, %	4	71.6 ± 3.2
Acid detergent fiber, %	4	56.7 ± 9.7
Ash, %	4	9.8 ± 0.3
IDMD, %	18	42.7 ± 3.1

ME, Mcal kg^{-1} DM	18	1.45 ± 0.11
Total polyphenols, g kg^{-1} DM	4	17.27 ± 3.85
Non-tannin phenols, g kg^{-1} DM	4	0.80 ± 0.08
Condensed tannins, g kg^{-1} DM	4	5.77 ± 0.36
Hydrolysable tannins, g kg^{-1} DM	4	10.71 ± 3.84
Total tannins, g kg^{-1} DM	4	16.48 ± 3.80

Previous studies indicate that foliage contains phenolic compounds, including CT which can reduce IDMD and mitigate gastrointestinal nematodes infections in sheep[33]. However, the CT content in *E. americana* observed in the present results (5.77 g kg^{-1} foliage DM) was less than half that reported for *E. goldmanii* (16.3 g kg^{-1} foliage DM)[9]. Differences in *Erythrina* CT content can be attributed to harvest season, foliage age, species and foliage drying method[9,34]. The relatively low foliage CT concentration in the present study can be partially attributed to the drying method since a delay in the drying process can allow enzymes in the plant to react with phenolic compounds[34]. In intact plant tissue, phenolic compounds are found in vacuoles in free form or linked to carbohydrates. However, when the foliage is harvested and air dried, plant tissue dehydration begins which leads to cell membrane and organelles damage, releasing enzymes that can decompose phenolic compounds. For example, the enzymes peroxidase and polyphenol oxidase are located in the chloroplasts and when these are damaged they produce hydroxylation and oxidation of phenolic compounds, forming quinones and then dark pigments called melanins[35,36].

Dry matter and nutrient intake

No interaction (P>0.05) was found between the studied factors. The light LWC sheep exhibited higher DM, CP, ME and CT intakes than the heavy LWC sheep (Table 2). This higher nutrient intake in the light sheep can be attributed to their not yet having reached mature weight[37,38]. Concentrations of CT greater than 5% in diet DM and the high effectiveness of CT in forming complexes with saliva proteins can reduce DM intake in sheep[33]. However, no reduction in DM intake was observed, probably because the *E. americana* used in the present study had a low CT level.

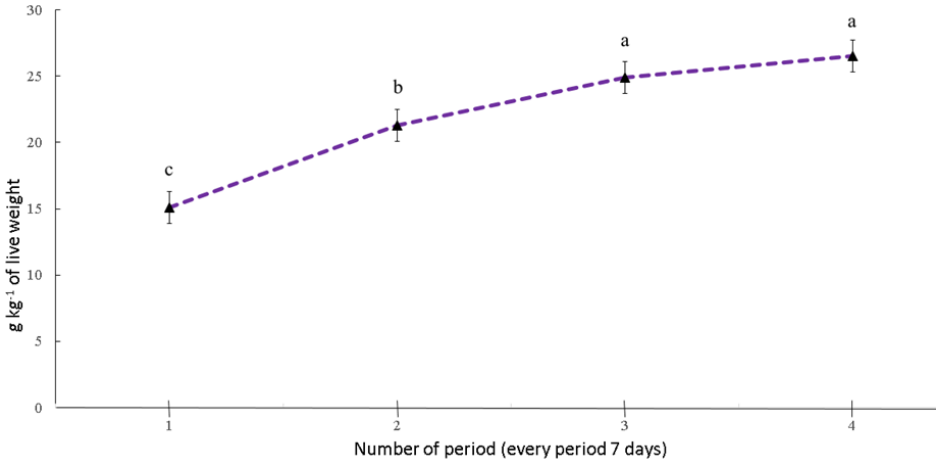
Table 2: Dry matter, crude protein, metabolizable energy and condensed tannins intakes by live weight category (LWC) in Blackbelly x Pelibuey sheep fed *Erythrina americana* foliage (means ± standard error)

Variable	Factor			LWC	
	LWC	EP	LWC x EP	Light¥	Heavyφ
Intake index, %	**	**	ns	$2.5^{a} \pm 0.1$	$1.9^{b} \pm 0.1$
DM intake, g kg^{-1} LW	**	**	ns	$24.7^{a} \pm 0.9$	$19.2^{b} \pm 0.8$
CP intake, g kg^{-1} LW	**	**	ns	$4.6^{a} \pm 0.2$	$3.6^{b} \pm 0.2$
ME intake, Mcal kg^{-1} LW	**	**	ns	$0.036^{a} \pm 0.001$	$0.028^{b} \pm 0.001$
CT intake, g kg^{-1} LW	**	**	ns	$0.142^{a} \pm 0.005$	$0.111^{b} \pm 0.005$

¥ Each value is the average of four sheep; φ Each value is the average of five sheep; EP= evaluation period; LW= live weight; DM = dry matter; CP = crude protein; ME= metabolizable energy; CT= condensed tannins. ** Significant (P<0.01); ns= not significant. ^{a,b} Different letter superscripts in the same row indicate significant difference (P<0.01).

The IDMD, and DM, nutrient and CT intakes increased up to the third week (Figure 1), after which nutrient intake remained constant. In a study of male Blackbelly sheep fed *E. poeppigiana* forage intake index was 3.5 %[11], which is higher than in the present results. Differences in IDMD between studies can be attributed to differences in *Erythrina* species chemical quality, sheep sex and breed[11,39]. Another consideration is that when sheep are fed diets containing CT, feed intake may decline due to an astringent reaction to the feed associated with formation of CT-protein complexes and reduction in IDMD[33]. This could at least partially explain the lower DM intake observed in the present study during the first two weeks of the trial. This response suggests that the sheep and their rumen reticulum microbes required a period of two weeks to adapt to the new diet. When sheep eat a diet containing CT their salivary glands produce proteins that bind to both CT and hydrolysable tannins, thus making them more tolerable[33,40]. In addition, ruminants exposed to diets with CT can develop microbe populations with the ability to alter and degrade CT, thereby preventing the animal from experiencing reductions in DM intake and/or IDMD[33,41].

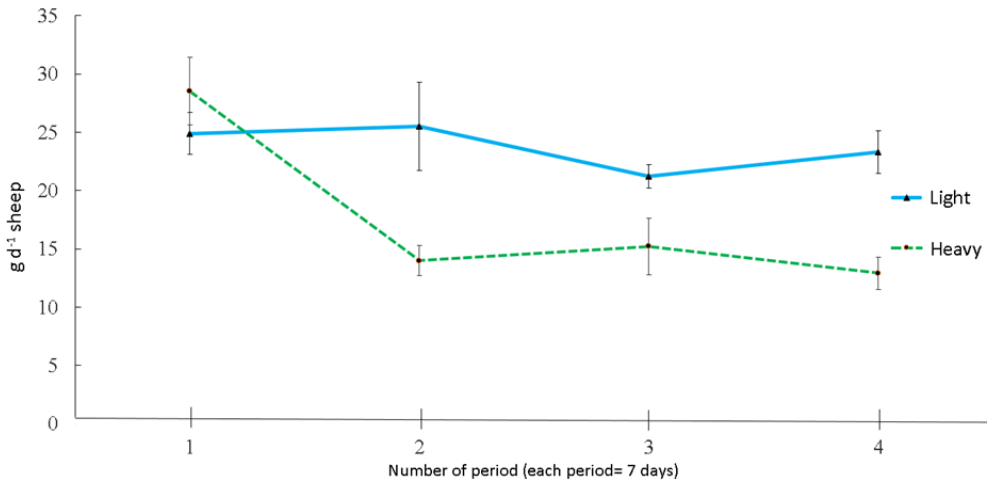
Figure 1: *Erythrina americana* foliage intake (g DM kg^{-1} LW) during feeding trial in Blackbelly x Pelibuey sheep



▲ Each value is the least mean square (± SE) of nine animals.
[abc] Different lowercase letters indicate significant difference (Student t test), $P<0.05$.

Mean (± SE) daily mineral salt intake was 23.7 ± 1.1 g animal^{-1} in the light LWC sheep and 17.6 ± 2.1 g animal^{-1} in the heavy LWC sheep. Mineral salt intake stabilized in both groups between the second and fourth week (Figure 2). Ash content (<10 %) in the *E. americana* foliage (Table 1) was within ranges reported for *E. americana* foliage of different regrowth ages[2,13,32]. Foliage from this tree legume has a lower ash content than tropical grasses such as *C. nlemfuensis* and *Panicum maximum*[42,43]. Consequently, it is important to provide mineral supplementation to sheep fed *E. americana*. In addition, the CT present in legumes can form complexes with some minerals, reducing their availability[33]. There are no studies to date on the mineral requirements of hair sheep under different feeding scenarios (grazing, penned)[44], but sheep fed *E. americana* exhibit higher mineral salt intake than hair sheep in a grazing system under a different feed supplementation regime[38,45,46]. Differences between studies can be attributed at least in part to sheep LW, feed supplement level and composition, mineral salt composition and season.

Figure 2: Mineral salt intake (g d^{-1} $sheep^{-1}$) by live weight category in Blackbelly x Pelibuey sheep fed *Erythrina americana*

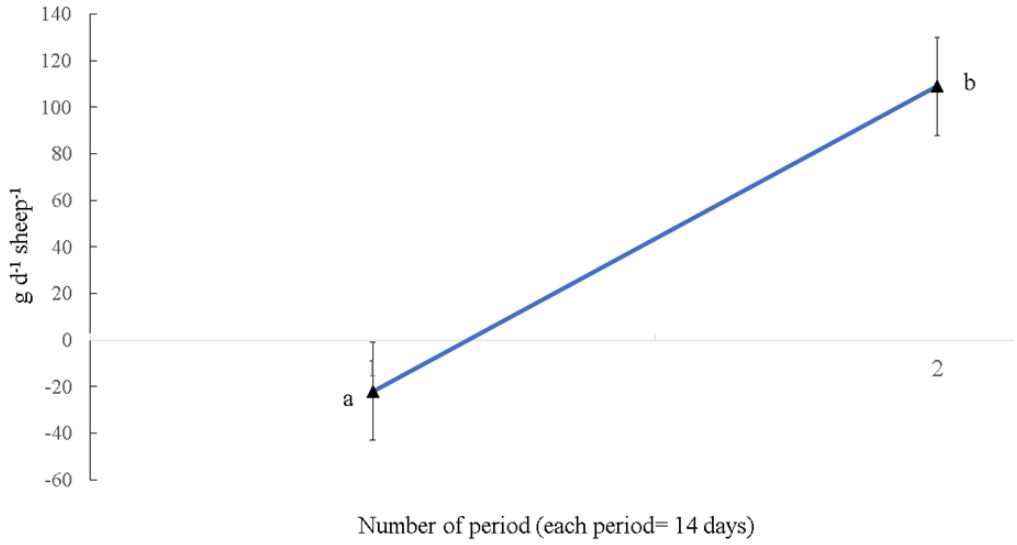


▲ Each value is the average (standard errors) of four sheep.
● Each value is the average (standard errors) of five sheep.

Changes in live weight

Sheep LWC and the LCW/EP interaction did not affect (P>0.05) DWG. However, EP alone did affect (P<0.01) DWG, since it was lower at fourteen days than at 28 d (Figure 3). The negative DWG observed at 14 d was probably due to lower nutrient intake (Figure 1). At 28 d, however, DWG increased substantially, a response that can be attributed to higher nutrient intake and compensatory growth[47,48].

Figure 3: Daily weight gain over time in Blackbelly x Pelibuey sheep fed *Erythrina americana* foliage



▲ Each value is the mean square (± standard errors) of nine sheep.
[ab] Different letters on the same line, indicate difference (test of "t"), $P<0.01$.

Total DWG, BC and FAMACHA index values were unaffected by LWC (Table 3). Total DWG in the present results was positive and higher than reported in male Pelibuey lambs fed *Pennisetum purpureum* and *E. poeppigiana*[12] but lower in growing Blackbelly male lambs fed only *E. poeppigiana* foliage. These differences in DWG between studies can be attributed to animal age, sex and breed[11].

Table 3: Changes in live weight, body condition and FAMACHA index values by live weight category (LWC) in Blackbelly x Pelibuey sheep fed *Erythrina americana* foliage (means ± standard error).

Variable	LWC	
	Light¥	**Heavyφ**
Initial weight, kg	$24.1^{b,} \pm 1.1$	$34.8^{a,} \pm 1.0$
Final weight, kg	$25.2^{b} \pm 1.0$	$36.1^{a} \pm 0.9$
Total DWG, g	40.5 ± 21.6	47.3 ± 19.3
Initial body condition	2.8 ± 0.3	3.0 ± 0.0
Final body condition	2.8 ± 0.3	3.0 ± 0.0
Intial FAMACHA	3.2 ± 0.5	3.0 ± 0.0
Final FAMACHA	3.2 ± 0.5	3.0 ± 0.0

¥ Each value is the average of four sheep; φ Each value is the average of five sheep.
[ab] Different lowercase letters indicate significant difference (P<0.01).

Blood components

No interaction (P>0.05) was found between the studied blood components. Day number (i.e. 1, 14 and 28 d) only affected (P<0.05) hemoglobin and hematocrit levels. The general mean (± SD) was 8.1 ± 1.5 (x 10^{12} L) for red blood cells; 10.2 ± 1.6 (g dl^{-1}) for hemoglobin; 25.1 ± 4.1 (%) for hematocrit; 31.2 ± 1.9 (x 10^{15} L) for mean red blood cell corpuscular volume; 10.2 ± 2.8 (x 10^{9} L) for white blood cells; 7.3 ± 2.2 (x 10^{9} L) for lymphocytes; and 1.0 ± 0.3 (x 10^{9} L) for granulocytes. The least mean square (± SE) for hemoglobin (g dl^{-1}) was 11.2^{a} ± 0.5 at d 1, 10.1^{b} ± 0.5 at d 14 and 9.4^{b} ± 0.5 at d 28. For hematocrit they were 22.5^{b} ± 1.3 at d 1, 26.6^{a} ± 1.3 at d 14 and 26.9^{a} ± 1.3 at d 28. The blood variable values observed in the present results are within the ranges reported for grazing hair sheep in tropical regions[49]. *Erythrina americana* foliage intake levels during the four-week feeding trial maintained blood variables at levels appropriate for non-gestating, non-lactating sheep.

Gastrointestinal nematode eggs

None of the studied factors affected EGF (P>0.05), and the overall mean (± SD; unprocessed data) for EGF was 264 ± 670. Consumption of CT in the diet (15 % CT from *Acasia molissima*, based on DM) can reduce EGF in small ruminants[15,33], but the CT intake level in the present study was insufficient to detect any changes in EGF that could be attributed to

LWC or EP. In addition, in the present study the sheep were fed *E. americana* in pens and were thus prevented from sustaining a natural nematode infection level, explaining in part the low EGF values.

Conclusions and implications

Erythrina americana foliage can be used as the sole feed source in Blackbelly x Pelibuey sheep for short periods, as indicated by its CP, structural carbohydrates and CT contents, as well as voluntary intake levels. Live weight class (LWC) and EP number did affect nutrient and CT intake levels in that lighter sheep had higher nutrient and CT intake per kg LW than heavier sheep. However, over the 28-d feeding trial their higher nutrient intake did not result in greater increases in DWG in the lighter sheep than in the heavier sheep. In both live weight categories *E. americana* intake did not cause negative changes in their productive behavior and health status as quantified in DWG, blood variables and EGF. *Erythrina americana* should only be used as a sole feed source for short periods in response to environmental contingencies.

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Literature cited:

1. Rodríguez-Ramírez MR, González-Sotelo A, Yáñez-Muñoz A, Silva-Luna M, Gómez-Escobar CI. Composición química de recursos forrajeros para la alimentación de ovinos en Colima, México. Folleto técnico 3, Colima, México: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias; 2013.

2. Oliva-Hernández J, López-Herrera MA, Velázquez-Jiménez E, López-Enríquez G, Vélez-Pérez II. Eficiencia en la cosecha manual de follaje de moté (*Erythrina americana* Miller). Rev Mex Cienc Forest 2019;10(11):55-67.

3. Pinto R, Ramírez L, Kú VJC, Ortega L. Especies arbóreas y herbáceas forrajeras del sureste de México. Pastos y Forrajes 2002;25(3):171-180.

4. García-Mateos R, Soto-Hernández M, Vibrans H. *Erythrina americana* Miller ("Colorín": Fabaceae), a versatile resource from Mexico: A Review. Economic Botany 2001;55(3):391-400.

5. Enríquez QJF, Meléndez NF, Bolaños AED, Esqueda EVA. Producción y manejo de forrajes tropicales. Libro técnico 28, Veracruz, México: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. 2011.

6. Torres RJA, Castro FR, Grande CD. Cercas de uso pecuario en la cuenca del río La Antigua, México: Inventario florístico y costo de construcción. Zootecnia Trop 2008;26(3):279-283.

7. Grande CD, Villanueva LG, Maldonado GNM, Hernández DS. Las cercas vivas. En: Maldonado GNM (coordinador). Los sistemas silvopastoriles en Tabasco. Una opción para desarrollar una ganadería productiva y amigable con la naturaleza. Tabasco, México: Universidad Juárez Autónoma de Tabasco; 2013:23-39.

8. Zamora S, García J, Bonilla G, Aguilar H, Harvey CA, Ibrahim M. Uso de frutos y follaje arbóreo en la alimentación de vacunos en la época seca en Boaco, Nicaragua. Agroforestería en las Américas 2001;8(31):31-38.

9. Pinto R, Gómez H, Hernández A, Medina F, Martínez B, Aguilar VH, *et al*. Preferencia ovina de árboles forrajeros del Centro de Chiapas, México. Pastos y Forrajes 2003;26(4):329-334.

10. Best DA, Lara-Lara PE, Aguilar-Urquizo E, Cen-Chuc FE, Ku-Vera JC, Sanginés-García JR. In vivo digestibility and nitrogen balance in sheep diets with foliage of fodder trees in substitution for soybean meal. Agroforest Syst 2017;91(6):1079-1085.

11. Benavides J. Árboles y arbustos forrajeros: una alternativa agroforestal para la ganadería. En: Sánchez MD, Rosales M editores. Agroforestería para la producción animal en Latinoamérica. Roma, Italia: Organización de las Naciones Unidas para la Agricultura y la Alimentación; 1999. http://www.fao.org/docrep/014/x1213s/x1213s.pdf. Consultado 3 Dic, 2017.

12. Grande CJD. Los árboles forrajeros como recurso potencial para el desarrollo de sistemas silvopastoriles en la región de la sierra de Tabasco [tesis doctoral]. México, DF: Universidad Autónoma Metropolitana; 2010.

13. Hernández-Espinoza DF, Ramos-Juárez JA, López-Herrera MA, Lagunes-Espinoza LC, González-Garduño R, Oliva-Hernández J. Influencia de la edad de rebrote de *Erythrina americana* Miller sobre la composición química del follaje. En: Martínez HJ coordinador. Reunión Científica-Tecnológica Forestal y Agropecuaria Tabasco 2017 y VI Simposio Internacional en Producción Agroalimentaria Tropical. Tabasco. 2017:53-56.

14. Li YG, Tanner G, Larkin P. The DMACA–HCl Protocol and the threshold proanthocyanidin content for bloat safety in forage legumes. J Sci Food Agric 1996;70:89-101.

15. Borges DGL, Borges FA. Plants and their medicinal potential for controlling gastrointestinal nematodes in ruminants. Nematoda 2016;3:e92016.

16. INEGI. Anuario estadístico y geográfico de Tabasco. México: Instituto Nacional de Estadística y Geografía; 2017. http://internet.contenidos.inegi.org.mx/contenidos/Productos/prod_serv/contenidos/espanol/bvinegi/productos/nueva_estruc/anuarios_2017/702825095123.pdf. Consultado 3 Oct, 2018.

17. Latimer Jr. GM. Official Methods of Analysis of AOAC International. Maryland, USA: AOAC International; 2012.

18. Van Soest PJ, Robertson JD, Lewis BA. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J Dairy Sci 1991;74:3583-3597.

19. Ørskov ER, Hovell FD DeB, Mould F. The use of the nylon bag technique for the evaluation of feedstuffs. Trop Anim Prod 1980;5:195-213.

20. García-Trujillo R. Estudio en la aplicación de sistemas de expresión del valor nutritivo de los forrajes en Cuba y método de racionamiento [tesis doctorado]. Habana, Cuba: Instituto de Ciencia Animal; 1983.

21. Makkar HPS, Blummel M, Borowy NK, Becker K. Gravimetric determination of tannins and their correlations with chemical and protein precipitation methods. J Sci Food Agric 1993;61:161-165.

22. Porter LH, Hrstich LN, Chan BC. The conversion of procyanidins and prodelphinidins to cyaniding and delphinidin. Phytochem 1985;25(1):223-230.

23. Singh B, Sahoo A, Sharma R, Bhat TK. Effect of polyethylene glicol on gas production parameters and nitrogen disappearance of some tree forages. Anim Feed Sci Technol 2005;123-124:351-364.

24. Rana KK, Wadhwa M, Bakshi MPS. Seasonal variations in tannin profile of tree leaves. Asian-Australas J Anim Sci 2006;19:1134-1138.

25. Thomson J, Meyer H. Body condition scoring of sheep. Oregon, USA: Oregon State University Extension Service; 1994. https://ir.library.oregonstate.edu/downloads/9p290956v. Consultado 3 Oct, 2018.

26. van Wyk JA, Bath GF. The FAMACHA© system for managing haemonchosis in sheep and goats by clinically identifying individual animals for treatment. Vet Res 2002;33(5):509-29.

27. Ambrosio JR. Técnicas cuantitativas de Mc Master y Stoll. En: Escutia I, Quiroz H, Herrera D (editores). Diagnóstico de las parasitosis internas de los rumiantes domésticos y cerdos. DF, México: Asociación Mexicana de Parasitología Veterinaria; 1985:252-264.

28. Cody RP, Smith JK. 1991. Applied Statistics and the SAS programming language. 3rd ed. New York, USA: Elsevier Science Publishing Co. Inc.

29. SAS. SAS User´s Guide (Release 9.0). Cary NC, USA: SAS Inst. Inc. 2002.

30. Wang Z, Goonewardene LA. The use of MIXED models in the analysis of animal experiments with repeated measures data. Can J Anim Sci 2004;84:1-11.

31. Milton JS. Estadística para biología y ciencias de la salud. Madrid, España: Mc Graw-Hill Interamericana; 2007.

32. Reyes MF, Jiménez FG. Uso y valor nutritivo de árboles y arbustos con potencial forrajero en la región de la sierra, Tabasco, México. En: Sánchez DDC, Jiménez SR, López ANC, Gómez ME editores. Reunión Científica Tecnológica Forestal y Agropecuaria Tabasco 98. Tabasco. 1998:73-80.

33. Naumann HD, Tedeschi LO, Zeller WE, Huntley NF. The role of condensed tannins in ruminant animal production: advances, limitations and future directions. R Bras Zootec 2017;46(12):929-949.

34. FAO. Quantification of tannins in tree foliage. Vienna, Austria: Food Agricultural and Agricultural Organization/International Atomic Energy Agency; 2000 http://www-naweb.iaea.org/nafa/aph/public/pubd31022manual-tannin.pdf. Consultado 9 Sept, 2017.

35. Dicko MH, Gruppen H, Traoré AS, Voragen AGJ, van Berkel WJH. Phenolic compounds and related enzymes as determinants of sorghum for food use. Biotechnol Mol Biol Rev 2006;1(1):21-38.

36. Morante CJ, Agnieszka OA, Bru-Martínez R, Carranza PM, Pico-Saltos R, Nieto RE. Distribución, localización e inhibidores de las polifenol oxidasas en frutos y vegetales usados como alimento. Ciencia y Tecnología 2014;7(1):23-31.

37. Dzib CA, Ortiz de Montellano A, Torres-Hernández G. Variabilidad morfoestructural de ovinos Blackbelly en Campeche, México. Arch Zootec 2011;60(232):1291-1301.

38. Zamora-Zepeda R, Oliva-Hernández J, Hinojosa-Cuéllar JA. Complementación energética y proteínica en corderas Blackbelly x Pelibuey en pastoreo. Nova Scientia 2015;7(15):245-264.

39. Lewis RM, Emmans GC. Feed intake of sheep as affected by body weight, breed, sex, and feed composition. J Anim Sci 2010;88:467-480.

40. Ventura-Cordero J, Pech-Cervantes A, Sandoval-Castro CA, Torres-Acosta JFJ, González PPG, Sarmiento FLA. Relación herbívoro-tanino: adaptación de ovinos y caprinos a la vegetación rica en taninos de la península de Yucatán. Bioagrociencias 2013;6(1):19-25.

41. Smith AH, Zoetendal E, Mackie RI. Bacterial mechanisms to overcome inhibitory effects of dietary tannins. Microb Ecol 2005;50(2):197-205.

42. Juárez RAS, Cerrillo SMA, Gutierrez OE, Romero TEM, Colín NJ, Bernal BH. Estimación del valor nutricional de pastos tropicales a partir de análisis convencionales y de la producción de gas *in vitro*. Tec Pecu Mex 2009;47(1):55-67.

43. Villalobos L, Arce J. Evaluación agronómica y nutricional del pasto Estrella Africana (*Cynodon nlemfuensis*) en la zona de monteverde, Puntarenas, Costa Rica. II Valor nutricional. Agron Costarricence 2014;38(1):133-145.

44. Oliva HJ. Crecimiento y desarrollo postdestete de corderas de razas de pelo. Explotación en pastoreo y con complementación alimenticia en regiones tropicales. Saarbrücken, Alemania: Editorial Académica Española; 2012.

45. Pascual-Córdova A, Oliva-Hernández J, Hernández-Sánchez D, Torres-Hernández G, Suárez-Oporta ME, Hinojosa-Cuéllar JA. Crecimiento postdestete y eficiencia reproductiva de corderas Pelibuey con un sistema de alimentación intensiva. Arch Med Vet 2009;41:205-212.

46. Cadenas JA, Oliva-Hernández J, Hinojosa JA, Torres-Hernández G. Suplementación alimenticia durante el crecimiento post destete de corderas Pelibuey x Blackbelly en pastoreo en el trópico húmedo de México. Arch Zootec 2010;59(226):303-306.

47. Lawrence TLJ, Fowler VR. Growth of farm animals. 2nd ed. NY, USA: CABI Publishing; 2002.

48. Manni K, Rinne M, Joki-Tokola E, Huuskonen A. Effects of different restricted feeding strategies on performance of growing and finishing dairy bulls offered grass silage and barley based diets. Agr FSci 2017;26:91-101.

49. Bezerra LR, Oliveira WDC, Silva TPD, Torreão JNC, Marques CAT, Araújo MJ, *et al*. Comparative hematological analysis of Morada Nova and Santa Inês ewes in all reproductive stages. Pesq Vet Bras 2017;37(4):408-414.