Revista **U.D.C.A** Actualidad & Divulgación Científica
July-December 2023-Volumen 26 No. 2:e2423
ISSN: 2619-2551 en línea
ISSN: 0123-4226 impreso

Scientific Article
http://doi.org/10.31910/rudca.v26.n2.2023.2423

Estimating carcass yield of lambs fed with silage of *Cenchrus purpureus* in a mix with T*ithonia diversifolia*

Rendimiento en canal de ovinos alimentados con ensilaje de *Cenchrus purpureus* en mezcla con *Tithonia diversifolia*

María Alexandra Huertas-González[1]*; Jairo Mora-Delgado[2]; Vilma Amparo Holguín-Castaño[3]

[1]Universidad del Tolima, Grupo de investigación en Sistemas Agroforestales Pecuarios, Ibagué - Tolima, Colombia; e-mail: mariahuertasg@ut.edu.co
[2]Universidad del Tolima, Departamento de Producción Pecuaria. Ibagué - Tolima, Colombia; e-mail: jrmora@ut.edu.co
[3]Q.E.P.D
*corresponding author: mariahuertasg@ut.edu.co

How to cite: Huertas-González, M.A.; Mora-Delgado, J.; Holguín-Castaño, V.A. 2023. Estimating carcass yield of lambs fed with silage of *Cenchrus purpureus* in a mix with *Tithonia diversifolia*. Rev. U.D.C.A Act. & Div. Cient. 26(2):e2423. http://doi.org/10.31910/rudca.v26.n2.2023.2423

Received: March 3, 2022 **Accepted:** June 23, 2023 **Edited by:** Helber Adrián Arévalo Maldonado

ABSTRACT

Small ruminant production is currently booming due to its ease of management and contribution to strengthening the food security of rural communities. In this experiment, it was evaluated the effect of feeding with *Cenchrus purpureus* silages in a mixture with *Tithonia diversifolia* on the carcass yield and bromatological quality of lambs, with an average weight of 23 kg, fed with silages (treatments): T1 *C. purpureus* in 100 % and T2 *C. purpureus*/*T. diversifolia* in proportion of 67/33 %, respectively. The silages were supplied for 61 days, with an energy supplement of rice flour (277 g/animal), mineralized salt, and water *ad libitum*. Carcass yield and food consumption were evaluated. The data was analyzed in a totally randomized design with five repetitions; an ANOVA was made and for the comparison of means, the Fisher LSD test was used. The average daily consumption of dry matter was better for T2 showing statistical differences ($p < 0.0001$), the characteristics of the carcass in this treatment were also better; significant differences were found in the nutritional value of the meat, showing better values in T2, for protein, humidity and for the colorimetric variables, because T1, exhibited darker meat, coinciding with the highest pH values (6.15). It is concluded that the *C. purpureus* silage diet in mixture with *T. diversifolia*, contributes to the improvement of the quality of the carcass.

Keywords: Animal production; Bromatology; Camuro; Small ruminants; Quality carcass.

RESUMEN

La producción de pequeños rumiantes es conocido por su facilidad de manejo y contribución al fortalecimiento de la seguridad alimentaria de comunidades rurales; sin embargo, debido a la baja calidad nutricional de las pasturas del trópico seco, esta industria experimenta problemáticas relacionadas con el producto final, lo que repercute en la productividad y el rendimiento. En este experimento, se evaluó el efecto de la alimentación con ensilajes de *Cenchrus purpureus*, en mezcla con *Tithonia diversifolia,* en el rendimiento en canal y calidad bromatológica de la carne de corderos, con peso promedio de 23 kg, alimentados con ensilajes (tratamientos): T1 *C. purpureus*, en 100 % y T2 *C. purpureus*/*T. diversifolia*, en proporción de 67/33 %, respectivamente. Los ensilajes, se suministraron durante 61 días, con un complemento energético de harina de arroz (277 g/animal), sal mineralizada y agua a voluntad. Se evaluó rendimiento en canal y consumo de alimento. Los datos, se analizaron en un diseño totalmente al azar, con cinco repeticiones; se hizo un ANDEVA y para la comparación de medias, se empleó la prueba de LSD Fisher. Se evaluó el consumo promedio diario de MS, los valores para rendimiento en canal y las características de la canal, además del valor nutricional de la carne. Se concluye que la dieta de ensilaje *C. purpureus* en mezcla con *T. diversifolia*, contribuye al mejoramiento de la calidad de la canal.

Palabras clave: Bromatología; Calidad canal; Camuro; Pequeños rumiantes; Producción animal.

INTRODUCTION

The introduction of small ruminants in livestock production has been increasing in various areas of Colombia, because these animals, especially those of the pelibuey breed, because their rusticity has an advantage of superior adaptation to other breeds (Aguilar-Martínez *et al.* 2017), to live in dry and tropical climates, besides being an important source of food resources for rural communities, being for this reason necessary to specify that the quality of the sheep meat is also valued by factors such as tenderness, taste, the juiciness, the degree of fatness and general appearance (Campo *et al.* 2008). Also, the chemical composition of the meat has special relevance in the quality of the food product, being an important component in the human diet; therefore, it is important to study and know the quality characteristics of the meat of this species, and in this way to argue its zootechnical potential and thus plan its management and nutrition with interesting food sources from the productive point of view, which when implemented, they can be potential to contribute positively in a production.

It is necessary to note that methane emissions at the enteric level in livestock production systems in tropical regions can be important because the production of forage in dry tropical conditions is affected by climatic seasonality due to the scarcity of food and therefore the availability of nutrients for animal production decreases considerably (Ulukan, 2011), as low levels of digestible protein and high fiber content. Phenomena that encourage the search for food alternatives within the farm's resources, integrating different tree and shrub species with high nutritional potential, to reduce food costs and improve animal response and zootechnical indexes, such as the production of meat and/or milk.

Therefore, the incorporation of vegetable woody protein species such as *T. diversifolia* has become an animal feeding strategy. Mahecha & Rosales (2005) reported high contents of total nitrogen, a high proportion of nitrogen of an amino acid nature, a high content of phosphorus, a rapid degradability and ruminal fermentation, a low proportion of Nitrogen linked to insoluble dietary fiber, as well as a low fiber content and secondary metabolism compounds; there is also evidence that this plant can accumulate between 15-33 % of crude protein (CP) of nitrogen in its leaves, as some legumes, has high levels of phosphorus, large root volume, ability to extract nutrients from the soil, a wide range of adaptation, tolerance to acid and infertile soils, is very rustic and can withstand pruning at ground level and burning (CIPAV, 2004). In addition to the above, this species has a rapid growth and low demand for inputs for planting (Ríos, 2002). Vargas Velázquez *et al.* (2022) reported important consumptions of diets supplied to sheep, which were mixed with *T. diversifolia* in pre-blossoming when this species has higher protein contents, which also demonstrates the palatability of the same and the possibility of using this species in the feeding of small ruminants.

Additionally, it has been demonstrated that *T. diversifolia,* thanks to its composition of secondary metabolites, is a forage specie with the potential to reduce methane production and the population of ruminal protozoa (Galindo *et al.* 2014). The inclusion of a non-legume species such as *T. diversifolia*, an improvement in the quality of the traditional diet based on grasses is observed, since this species has been characterized as potential in the supply of protein, in addition to having a high degradability at the ruminal level, in addition to its low fiber content. This makes it possible to ensure that the inclusion of *T. diversifolia* contributes to the sustainability of the productive systems by decreasing methane emissions.

For these reasons, the objective of this work was to determine the carcass yield of sheep pelibuey breeds fed with silages of *Cenchrus purpureus* mixed with *Tithonia diversifolia.*

MATERIALS AND METHODS

Location. The study was conducted at the Mario González Aranda experimental farm of the Universidad Nacional de Colombia, located in Palmira, Valle del Cauca; with an average annual precipitation of 1,000 mm, an average temperature of 24 °C and an altitude above sea level of 1,000 m located between 3°30'29" N and 76°18'45" W (Holguín *et al.* 2018), zone classified as tropical dry forest (Holdridge, 1987). The experiment took place in a corral with an area of 3.70 x 8.30 meters, divided into two areas, allocating approximately 4 meters for each treatment, the corrals were built on plastic floor and wood, each of which had built-in feeders with corrugated PVC split in half and devices for the administration of salt and water**.**

Animals and treatments: Ten experimental animals were used, whole male sheep, known as camuro or furry sheep, with an average weight of 22.6 ± 2.2 kg. The experiment was developed for eight weeks, with a previous acclimatization period of fifteen days for the animals.

The weighing of the animals was done at the beginning, at 30 days and at the end of the experiment, the weight data were taken at 7:00 am. The first weighing was performed after 5 days of habituation to the silage diet and 10 days to the different treatments, as shown in table 1.

A Crane Scale electronic scale was used to measure weights. To determine the weight gain, the final weight difference minus the initial weight was estimated and divided by the number of days of the experimental period. The animals were randomly distributed in two treatments: T1: *Cenchrus purpureus* silage and rice flour supplement as energy base. T2: *Cenchrus purpureus* silage (67 %) in a mixture with *Tithonia diversifolia* (33 %) and rice flour supplement as an energy base. The food was administered twice daily (7 and 16 hours) in feeders installed inside each of the corrals; the consumption of food was estimated in each supply, in each of which, before the administration of the diet, the surplus of the feeders was weighed. The supply of dry matter (DM) was adjusted according to the stage of growth of the animals, estimating an average DM consumption of 3.5 % based on the Basic manual of nutrition and feeding of sheep by Castellaro *et al.* (2015). The rice flour was supplied as an energy source in equal proportion for both treatments (277 g/animal). The composition of this source was 91 % DM; 11.3 % of PC; 27.4 % of (NDF) and 14.3 % of (ADF). Water and salt were supplied *ad libitum***.**

Silage elaboration: The forage of *C. purpureus* and *T. diversifolia* was harvested at 60 and 90 days correspondingly, in addition, they were pre-dried to lower the moisture content. Then, the particle was reduced to 2 cm. In a mill with three blades, 7.5 HP, 1400 rpm, and 4.5 Amperes Gaitán's brand. Once the forage was chopped separately, the LAB T735 inoculum was mixed and sprayed in layers at a concentration of 30 x 107 cfu/ml. Thus, 3.3 Ton of *C. purpureus* and 3.1 t of the mixture *T. diversifolia* / *C. purpureus* (TD/CP) were prepared with a proportion of 33 and 67 % respectively, as this is the most adequate nutritionally and environmentally as demonstrated by Holguín *et al.* (2018). The filling and compaction of the bags of the silages were done with a compactor machine INVENTO brand with a yield of 0.4 Ton/hour. A double bag of 7-gauge black polyethylene was used, which were stored on wooden pallets for 90 days. The silages were inoculated with *Lactobacillus paracasei* (T735). The bacterial strains used as silage additives were produced in the Clinical Laboratory of the Universidad del Tolima.

Table 1. Weight of the furry sheep before the experimental period for the evaluation of diets of *Cenchrus purpureus* only (T1) and in a mixture with *Tithonia diversifolia* (T2).

Treatment	Weight on arrival	Final Wright acclimatization	Start weight of the experiment
T1	23.0 ± 2.03 a	23.0 ± 2.0 a	23.3 ±1.4 a
T2	22.0 ± 2.40a	23.0 ± 2.4 a	23.6 ±1.9 a
Total	22.6 ± 2.2 a	23.0 ± 2.0 a	23.5 ±1.5 a

Values with the same letter have no significant statistical difference (p> 0.05). Mean ± standard deviation.

Table 2 shows the bromatological composition of the silage which was carried out in the Animal Ecophysiology laboratory of the Universidad del Tolima and in the forage laboratory of CIAT, where neutral detergent fiber (NDF), acid detergent fiber (ADF) was determined, according to the method described by Van Soest & Wine (1967), crude protein (CP) according to the method of Kjeldahl (Nielsen, 1994) and dry matter (DM) and ash employing the fixed mineral residue method described by the AOAC (1990) in a stove (Presitiontm) at 63 °C for 72 h. Digestibility of *in vitro* dry matter (DIVDM) was determined by AOAC procedures 984.13.

Table 2. Bromatological analysis of diets supplied to experimental furry sheep animals within the trial.

Variable	Units	T1 *Cenchrus purpureus* (100 %)	T2 *Cenchrus purpureus*/ *Tithonia diversifolia* (67 % / 33 %)
DM	%	15.2 ± 0.31 a	17.79 ± 0.55 b
CP	%	6.52 ± 0.48 a	7.45 ± 0.2 a
NDF	%	69.5 ± 0.19 b	56.41 ± 0.07 a
ADF	%	51.02 ± 0.00 a	49.92 ± 0.18 a
Ash	%	16.4 ± 0.91 b	13.79 ± 0.38 a

DM: dry matter; CP: crude protein; NDF: neutral detergent fiber; ADF: acid detergent fiber. Values with different letters have significant statistical differences (p <0.05). Mean ± standard deviation.

The benefit of the animals and carcass yield. This activity was carried out in the slaughter plant of the Mario González Aranda experimental farm of the Universidad Nacional de Colombia, located in Palmira, Valle del Cauca. The weight of the animals was registered after an 8-hour fast, necessary for the benefit, which was developed in an artisanal way, through desensitization with the separation of the occipito-alantoid joint, subsequently, the animals were slaughtered, bled, skinned, eviscerated, separated the head at the level of the occipito-atloid joint, the limbs were removed, which are cut at the level of the carpo-metacarpal and tarso-metatarsal joints, keeping the tail. Just after the slaughter, the weight of the hot carcass (HC) was recorded.

Bioethics concept was not required because the animals were not intervened with invasive practices; the animals were sacrificed at the recommended age, in the slaughterhouse of the Universidad Nacional de Colombia (Palmira), following the technical and animal welfare protocols.

The chest depth (CD) was determined: by measuring with a tape measure on the medial side of the inner side, from the inner edge of the spinal column at the level of the 5th or 6th dorsal vertebra to the external or lower edge of the sternal cartilage; Carcass length (CL): measured from the anterior edge of the ischiopubic symphysis to the cranial edge of the first rib at its midpoint; leg length (LL): measured from the anterior edge of the pubic symphysis to the inner side of the tarsal-metatarsal joint; the perimeter of the leg (LP): with a tape measure is measured at the height of the line of the maximum perimeter of the leg. The cold carcass weight (CCW), after cooling the carcass, was recorded for 24 h at 4 °C.

Bromatology and meat quality: The chemical analyses of the meat were carried out in measured in cuts of the *Longissimus dorsi* muscle, taken after cooling the carcass for 24 hours at 4 °C. The Laboratory of extension services in chemical analysis LASEREX, attached to the Departamento de Química of the Facultad de Ciencias of the Universidad del Tolima, was responsible for developing the bromatological and quality analyzes of these samples.

Meat Color: The color characteristics of the samples, were measured in the Post-harvest Laboratory of the Universidad del Tolima, with the portable colorimeter CR-400 (Konika Minolta). For each sample refrigerated for 36 hours, measurements were made at 10 different points on the sample surface and then averaged. The data are presented as three-dimensional coordinates in the CIELab colorimetric system, such as L *, a *, and b *corresponding to the range of black, green, red, and yellow-blue, white, respectively (León *et al.* 2006).

Statistical Analysis: The data were analyzed through an ANOVA with a completely randomized design, with two treatments (T1: 100% *Cenchrus purpureus* silage and T2: *Cenchrus purpureus* silage mixed with *Tithonia diversifolia* at 33 and 67%, respectively). Five repetitions per treatment. The following statistical model was used:

$$Yij=\mu+Ti+Eij$$

Where: Y = response variable to be evaluated in treatment i, repetition j; Ti = effect of the treatment i; Eij = experimental error.

For the comparison of means of the variable weight gain, the Tukey test was used, and the Fisher LDS test was used for the performance variables and characteristics of the carcass and meat. The level of pre-established significance was 5%. For the analysis of the data, the statistical package Infostat (version 2018) was used.

RESULTS AND DISCUSSION

Dry matter consumption. Total consumption in the experimental period was higher in T2, which means a daily average of DM consumed by animals fed *Cenchrus purpureus* (T1) grass silage of 323.0 ± 65.3 g and 410.2 ± 65.3 for those fed with *C. purpureus/T. diversifolia* silage (T2), with statistical differences among them (P <0.0001) (Holguín *et al.* 2018). This corresponds to a real DM consumption for the T1 and T2 treatments of 3.6 and 3.5 %, respectively, of the live weight; it is likely that a higher concentration of NDF in the T1 diet has depressed the intake; thus, DM consumption was lower than the standards reported in different studies, as the Castellaro *et al.* (2015), who reported values of 4 %.

Weight Gain. Figure 1 shows the data of weight gain (WI), there are values of 3.86 ± 1.39 kg/animal for T2 and a weight loss for T1, this is consistent with the daily weight gain (DWG) in the four weeks evaluated, resulting in 63.3 ± 22.82 g per day in the diet that included *T. diversifolia* (Holguín *et al.* 2018). This response was superior to those reported with diets supplemented with other woody protein sources such as *Leucaena leucocephala*, *Guazuma ulmifolia*, *Gliricidia sepium*, and *Senna spectabillis* with values ranging between 12 and 53 g/animal/day (Medina & Sánchez, 2006), although inferior to those presented in studies supplemented with other protein sources, with gains between 85 and 116 g/animal/day (Clavero *et al.* 1995; Espinoza *et al.* 2001).

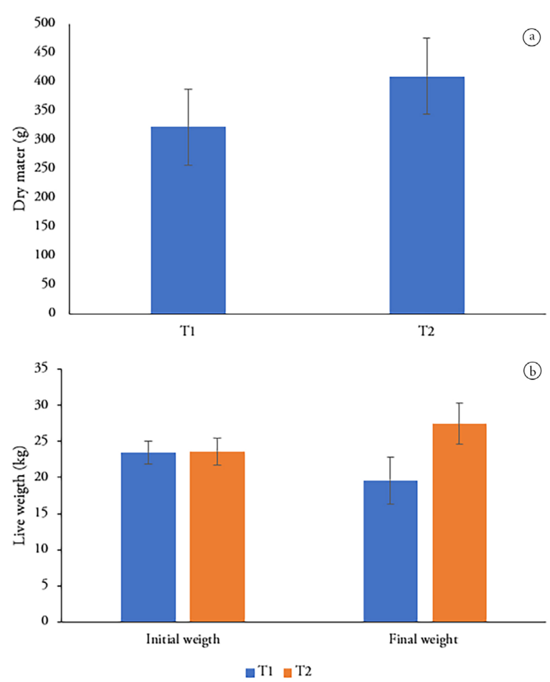

Figure 1. Food consumption and weight gain of fed lambs with silage *Cenchrus purpureus* (T1) and *Cenchrus purpureus* mixed with *Tithonia diversifolia* (T2) (Holguín *et al*. 2018). a) Dry matter consumption; b) weight gain.

The values of weight gain in the evaluated period, accumulated by treatment, denote an increase between the initial weight and the final weight of 3.52 ± 1.39 kg/animal for the T2 treatment and a weight loss for the T1 (Holguín *et al.* 2018). The same positive response to daily weight gain (DWG) was obtained in the 61 days evaluated for T2 (0.05 ± 0.02 g). These values were very similar to those reported by Medina & Sánchez (2006), with values between 0.044 and 0.051 kg/animal/day, with diets supplemented with *Leucaena* and multi-nutritional blocks, respectively.

Carcass yield and characteristics. In table 3 it is possible to see the quantitative values of the variables to determine the characteristics of the carcass, where statistical differences between treatments are observed for the weight of the hot carcass, weight of the cold carcass, length of the carcass, and perimeter of the leg; breast depth and carcass yield did not show statistical differences.

These data characterize the quality of the carcass, this concept is defined as the set of quantitative and qualitative characteristics, whose relative importance gives the carcass a maximum acceptance and a higher price compared to consumers or market demand. Thus, the morphological characteristics of the experimental animals, belonging to each group, show similarities to the values obtained by García Macías *et al.* (1998) as the variables of length of the carcass (52.64 ± 1.59 cm) and chest depth (24.54 ± 0.79 cm).

Table 3. Characteristics of the furry sheep carcass fed with silages of *Cenchrus purpureus* mixed with *Tithonia diversifolia*.

Carcass characteristics	**T1** *Cenchrus purpureus* (100 %)	**T2** *Cenchrus purpureus/ Tithonia diversifolia* (67 % / 33 %)
Weight of the hot carcass (HC) Kg	6.8 ± 0.44 a	9.4 ± 0.44 b
Weight of the cold carcass (CC) Kg	6.6 ± 0.41 a	9.35 ± 0.44 b
Canal length (CL) cm	60 ± 0.77 a	67.3 ± 0.96 b
Leg length (LL) cm	31 ± 1.28 a	31.4 ± 1.05 a
Perimeter of the leg (LP) cm	25 ± 0.74 a	29.8 ± 1.24 b
Chest depth (CD) cm	26 ± 0.76 a	27.6 ± 0.73 a
Carcass yield %	36 ± 3.6 a	36.7 ± 0.58 a

Values with different letters (a, b) have significant statistical differences ($p < 0.05$). Mean ± standard deviation.

Concerning the variables of the weight of the hot carcass and weight of the cold carcass, the average values found in this study are close, although slightly lower than the results found by García Macías *et al.* (1998) 10.46 ± 0.71 and 10.46 ± 0.8 respectively; by Frías *et al.* (2011) 13.5 ± 0.47 and 12.94 ± 0.45; Campo *et al.* (2008) report higher values for the carcass yield 50.3 ± 0.57, the foregoing is possibly explained because the experimental animals of this study did not reach higher weights during the project phase.

Bromatology and quality of meat. In table 4 it is possible to see the results of the chemical analysis of meat samples from the *Longissimus dorsi* muscle of the animals of the experimental groups of this study.

Campo *et al.* (2008) reported values of humidity percentage of 76.4 ± 0.43 %; which are like those found in this study for the group fed the silo of mixed *Tithonia diversifolia*, the values reported in this study for the control group were slightly higher than those found by these researchers; there is statistical significance for this variable between the two experimental groups.

In this work, higher values were found for the percentage of ether extract for T1, however, slightly higher than those of T2, to those reported in Aragonese, Churra, and Spanish merino sheep 12 ± 2.62 %, 13.08 ± 3.40 %, and 12.68 ± 2.58 % respectively (Campo *et al.* 2008), statistical significance was found for this variable between the two study groups. It must be considered that the fat content of sheep meat is very variable, finding values ranging from 3 to 30 % (Varela Moreiras *et al.* 2009), a situation that depends on factors such as age, animal sex, feeding, and area of the carcass where the meat sample is taken.

Additionally, it is known that sheep meat has between 20-25 % protein, being a molecule of high biological value for human consumption, since almost 40 % of its amino acids are essential (Valero Gaspar *et al.* 2018), a condition that decreases with the age of the animal (Varela Moreiras *et al.* 2009). In this experiment, significant differences were found between the two groups studied, observing values like those found by García Macías *et al.* (1998) in the *Longissimus dorsi* muscle of castrated lambs.

Table 4. Bromatology of the meat of furry sheep fed with silages of *Cenchrus purpureus* mixed with *Tithonia diversifolia*.

Variable	**T1** *Cenchrus purpureus* (100 %)	**T2** *Cenchrus purpureus/ Tithonia diversifolia* (67 % / 33 %)
Moisture %	81.76 ± 0.19 b	76.44 ± 0.19 a
Dry matter %	18.24 ± 0.19 a	23.56 ± 0.19 b
Ash %	4.44 ± 0.08 b	3.54 ± 0.08 a
Crude Protein %	14.98 ± 0.19 a	18.84 ± 0.19 b
Ether extract %	15.2 ± 0.39 b	6.1 ± 0.39 a
Crude Fibre %	1.58 ± 0.08 b	1.12 ± 0.08 a
Calcium %	0.33 ± 0.01 b	0.15 ± 0.01 a
Magnesium %	0.13 ± 0.00 b	0.11 ± 0.00 a
Sodium mg/Kg	754.78 ± 13.62 a	744.64 ± 13.62 a
Potassium %	0.76 ± 0.01 a	0.93 ± 0.01 b
Iron mg/Kg	284.24 ± 0.63 b	166.94 ± 0.63 a
Copper mg/Kg	4.42 ± 0.08 b	3.64 ± 0.08 a
Zinc mg/Kg	81.1 ± 0.31 b	62.1 ± 0.31 a
Phosphorus %	0.61 ± 0.00 b	0.43 ± 0.00 a
Sulfur %	0.03 ± 0.01 a	0.04 ± 0.01 a
Boron mg/Kg	<0.04	<0.04
Manganese mg/Kg	<0.3	<0.3

Values with different letters have significant statistical differences ($p < 0.05$). Mean ± standard deviation.

On the other hand, significant differences were found between the groups studied for ash percentage values, which are lower than those reported by Rahman *et al.* (2012) in goat meat, who also state that the age of the animal to which the slaughter is made has important effects on the physicochemical characteristics of the meat and in particular on the ash content. It is important to note that, when it comes to the nutritional quality of meat, it is not common to consider the mineral composition of meat, however, this is an aspect that is important in human nutrition and its need for nutrients.

The meat of sheep is an excellent natural source of iron and zinc of high bioavailability, being the indispensable iron for the formation of red globules and the zinc important for the good operation of the immunological system (Galán *et al*. 2013). Sheep meat also provides potassium and phosphorus. Being one of the meats with the lowest sodium content with 970 mg/1Kg (NRC, 2006).

Color of the meat. The meat is composed of fractions of fat and muscle, the concentration of myoglobin and its structure influence the amount of reflected light, which is translated into the color of the meat (Cañeque & Sañudo, 2005). The color of the meat changes in response both to the amount of myoglobin it contains and to the chemical changes in the myoglobin itself (Larraín *et al.* 2008), thus, the greater the amount of myoglobin in the meat, the darker the observed color. Older animals contain more muscle myoglobin and, therefore, have darker flesh than young animals. The muscular pH directly affects the color of the meat; at a high pH, the muscle has a closed structure and, therefore, it seems dark and the meat tends to be hard (Sebsibe, 2008).

The color of the raw meat is perceived as a visual characteristic, being one of the main factors that determine the productive value for the commercialization of this product, since the consumer relates the color with the sensory qualities of the meat; likewise, the color of the fat is an important aspect for the consumer, it is influenced by the chemical composition of the fatty acids that make up the subcutaneous and intramuscular fatty deposits (O'Sullivan *et al.* 2003), since the meat can also be discolored before reaching the point of sale if too much drying occurs, for its marketing it is preferred that the carcasses have at least some fat (subcutaneous fat) evenly distributed over the carcass since this aid to maintain the quality and attractive appearance by preventing the meat from drying out (Sebsibe, 2008).

L^*= Lightness

a^*= Red/green coordinates (+a indicates red, -a indicates green)

b^* = Yellow/blue coordinates (+b indicates yellow, -b indicates blue)

ΔL^* = Difference between light and dark (+= brighter, -= darker)

Δa^* = Difference between red and green (+ = more red, -= more green)

Δb^* = Difference between yellow and blue (+ = more yellow, -= more blue)

ΔE^* = Total color difference

As with the chemical characteristics of the meat, factors such as the species, the age of the animal, the breed, sex, and type of feeding, determine intrinsically the pigment content of the meat of the animal, the pH, and color of the meat, affecting the final value of the same, also conditions before and after the benefit of the animal, such as stress, temperature, humidity, storage time and marketing conditions among others (Cañeque & Sañudo, 2005).

The meat from the experimental groups exhibits statistical significance for the colorimetry variable; it is observed that the control group T1, exhibits darker meat (Table 5), coinciding with the highest pH values observed in table 6; less red and more yellow, compared to T2. Regarding the color difference, statistical significances are also found between both groups, it is corroborated that the T1 exhibits values of lower luminosity (Table 5), less red and more yellow. It is known that the chromatic coordinates a * and b * of the meat decrease during the storage period, translated into the dependence between these two colors coordinates, which shows that the loss of redness and the increase of the darkening of the product are the results of the formation of metamyoglobin, which finally causes the reduction of the value of b * (Esmer *et al.* 2011; Rosenvold & Wiklund, 2011).

In table 6 the differences found related to the pH of the meat measured 36 hours after slaughter are shown. Bianchi et al. (2006) indicated the relationship of pH with the degree of stress that the animal suffers before and during slaughter. The results in this work show a pH of 5.49 for T2, which is within the optimum ranges since it indicates adequate physicochemical characteristics, a good commercial life, and the presence of this pH value being an inhibitor of the growth of microorganisms. Values very similar to those found in this study for T2 were expressed by Rodrigues et al. (2008) in lambs Santa Ines breed fed in the final stage with citrus pulp, similarly, Zhang et al. (2005) reported similar pH data. Opposed to the evidence in T1, where pH values of 6.15 are observed, which are related to conditions of stress or physical exertion on the part of the animal, in this case, DFD meats are produced (dark, firm and hard) characterized by have a high capacity for water retention and favoring bacterial proliferation, the technological properties of which are altered; this can be explained due to the stress to which the animals of the control group were subjected when fed a fibrous diet and nutritionally poorer.

According to the results obtained, it is concluded that sheep pelibuey breed are animals with very good meat production which have optimal carcass for commercialization. Additionally, the characteristics of meat quality and carcass yield are within the normal ranges for lean meat.

Table 5. Colorimetry of the meat of furry sheep fed with silages of *Cenchrus purpureus* mixed with *Tithonia diversifolia.*

Color of the meat	**T1** *Cenchrus purpureus* (100 %)	**T2** *Cenchrus purpureus/* *Tithonia diversifolia* (67 % / 33 %)
L	40.56 ± 0.77 b	35.04 ± 0.77 a
a	14.49 ± 0.17 a	15.3 ± 0.17 b
b	4.29 ± 0.12 b	3.49 ± 0.12 a
Delta L	-54.04 ± 0.77 b	-48.52 ± 0.77 a
Delta a +	14.98 ± 0.17 a	15.78 ± 0.17 b
Delta b +	1.71 ± 0.12 b	0.91 ± 0.12 a
Delta E	50.83 ± 0.75 a	56.32 ± 0.75 b

Values with different letters have significant statistical differences (p <0.05). Mean ± standard deviation.

Table 6. pH measurement of furry sheep meat fed with silages of *Cenchrus purpureus* mixed with *Tithonia diversifolia.*

	T1 *Cenchrus purpureus* (100 %)	**T2** *Cenchrus purpureus/* *Tithonia diversifolia* (67 % / 33 %)
pH	6.15 ± 0.1 a	5.49 ± 0.1 b

Values with different letter have significant statistical difference (p <0.05). Mean ± standard deviation.

The supplementation of sheep with silages in a mixture with *Tithonia diversifolia* improves weight gain, which is reflected in the improvement of the characteristics of the carcass, increasing the zootechnical response of animal production. On the other hand, it was observed that in sheep-fed silage mixed with *Tithonia diversifolia,* the physicochemical characteristics of the meat are improved. It is suggested to carry out more studies that contribute to the understanding and analysis of alternative plant species for the nutrition of ruminants.

The shortage of food in regions of dry tropics due to the climatic seasonality, generates great preoccupation by the low supply of forage of good quality for the feeding of the livestock productions, more specifically of ruminants, bringing like consequence a diminution of the productive parameters.

In areas of dry tropics, during strong periods of drought, the inclusion of concentrated foods is considered a food alternative, however, most of the raw materials for its production are imported, which increases the final cost of the product. Th er efore it is necessary to look for strategies to overcome the situation described above, so it is recommended to deepen the knowledge of the plant species *Tithonia diversifolia* as a sustainable alternative for its nutritional supplementation, because thanks to its agronomic and chemical characteristics, this species has shown that in addition to being accepted by different animal species, it contributes to the improvement and increase of the zootechnical response of ruminant animals.

Acknowledgments. To the Universidad Nacional de Colombia, Palmira, for providing the spaces for the development of this experiment; CIAT International Center for Tropical Agriculture for allowing the use of equipment and laboratory analysis and the Central Office for Research and Scientific Development of the University of Tolima for the financing of this study. Conflict of interest: The manuscript was prepared and reviewed with the participation of all the authors, who declare that there is no conflict of interest that jeopardizes the validity of the results presented. Funding: The manuscript is result of the research Project "Rendimiento en canal y producción de gas metano en ovinos de pelo alimentados con ensilajes de *Penisetum purpureum* en mezcla con *Tithonia diversifolia*", funding by Oficina Central de Investigaciones of the Universidad del Tolima. Authors contribution: Project administration by Vilma A. Holguín (q.e.p.d.) and Jairo Mora-Delgado. Investigation and writing review by Maria Alexandra Huertas. Methodology by Vilma A. Holguín and Maria Alexandra Huertas. Conceptualization and supervision by Vilma A. Holguín. Formal analysis by Jairo Mora-Delgado.

REFERENCES

1. AGUILAR-MARTÍNEZ, C.U.; BERRUECOS-VILLALOBOS, J.M.; ESPINOZA-GUTIÉRREZ, B.; SEGURA-CORREA, J.C.; VALENCIA-MÉNDEZ, J.; ROLDÁN-ROLDÁN, A. 2017. Origen, historia y situación actual de la oveja pelibuey en México. Tropical and Subtropical Agroecosystems. 20(3):429-439.

2. ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS - AOAC. 1990. Official Methods of Analysis. Washington, D.C.

3. BIANCHI, G.; GARIBOTTO, G.; FEED, O.; BENTANCUR, O.; FRANCO, J. 2006. Efecto del peso al sacrificio sobre la calidad de la canal y de la carne de corderos Corriedale puros y cruza. Archivos de Medicina Veterinaria. 38(2):161-165. http://dx.doi.org/10.4067/S0301-732X2006000200010

4. CAMPO, M.M.; OLLETA, J.L.; SAÑUDO, C. 2008. Características de la carne de cordero con especial atención al Ternasco de Aragón. Agencia aragonesa de seguridad alimentaria. 50p.

5. CAÑEQUE, M.V.; SAÑUDO, A.C. 2005. Estandarización de las metodologías para evaluar la calidad del producto (animal vivo, canal, carne y grasa) en los rumiantes. INIA. 448p.

6. CASTELLARO, G.; ORELLANA, C.; ESCANILLA, J.P. 2015. Manual básico de nutrición y alimentación de ganado ovino. Facultad de Ciencias Agronómicas, Universidad de Chile. 56p.

7. CENTRO PARA LA INVESTIGACIÓN EN SISTEMAS SOSTENIBLES DE PRODUCCIÓN AGROPECUARIA - CIPAV. 2004. Sistemas Agroforestales, banco de forraje de leñosas, árboles y arbustos. In: Sistemas silvopastoriles. p.32-33.

8. CLAVERO, T.; MULLER, A.; RAZZ, R. 1995. Comportamiento de ovinos suplementados con Leucaena leucocephala. Revista Argentina de Producción Animal. 15:413-414.

9. ESMER, O.K.; IRKIN, R.; DEGIRMENCIOGLU, N.; DEGIRMENCIOGLU, A. 2011. The effects of modified atmosphere gas composition on microbiological criteria, color and oxidation values of minced beef meat. Meat science. 88(2):221-226. https://doi.org/10.1016/j.meatsci.2010.12.021

10. ESPINOZA, F.; ARAQUE, C.; LEÓN, L.; QUINTANA, H.; PERDOMO, E. 2001. Efecto del banco de proteína sobre la utilización del pasto estrella (*Cynodon lemfuensis*) en pastoreo con ovinos. Zootecnia Tropical. 19(3):307-318.

11. FRÍAS, J.C.; ARANDA, E.M.; RAMOS, J.A.; VÁZQUEZ, C.; DÍAZ, P. 2011. Calidad y rendimiento en canal de corderos en pastoreo suplementados con caña de azúcar fermentada. Avances en Investigación Agropecuaria. 15(3).

12. GALÁN, M.G.; GONZÁLEZ, R.J.; DRAGO, S.R. 2013. Perfil nutricional y dializabilidad de minerales de alimentos de interés social. Revista Española de Nutrición Humana y Dietética. 17(1):3-9. https://doi.org/10.14306/renhyd.17.1.2

13. GALINDO, J.; GONZÁLEZ, N.; MARRERO, Y.; SOSA, A.; RUIZ, T.; FEBLES, G.; TORRES, V.; ALDANA, A.; ACHANG, G.; MOREIRA, O.; SARDUY, L.; NODA, A. 2014. Efecto del follaje de plantas tropicales en el control de la producción de metano y la población de protozoos ruminales in vitro. Revista Cubana de Ciencia Agrícola. 48(4):359-364.

14. HOLDRIDGE, L.R. 1987. Ecología basada en zonas de vida. Instituto Interamericano de Cooperación para la Agricultura. San José, Costa Rica. 216p.

15. HOLGUÍN, V.; CUCHILLO-HILARIO, M.; MAZABEL PARRA, J.; MARTENS, S. 2018. In-vitro assessment for ensilabillity of *Tithonia diversifolia* alone or with P*ennisetum purpureum* using epiphytic lactic acid bacteria strains as inocula. Acta Scientiarum. Animal Sciences. 40:e37940. https://doi.org/10.4025/actascianimsci.v40i1.37940

16. LARRAÍN, R.E.; SCHAEFER, D.M.; REED, J.D. 2008. Use of digital images to estimate CIE color coordinates of beef. Food Research International. 41(4):380-385. https://doi.org/10.1016/j.foodres.2008.01.002

17. LEÓN, K.; MERY, D.; PEDRESCHI, F.; LEÓN, J. 2006. Color measurement in L* a* b* units from RGB digital images. Food research international. 39(10):1084-1091. https://doi.org/10.1016/j.foodres.2006.03.006

18. GARCÍA MACÍAS, J.A.; NUÑEZ GONZÁLEZ, F.A.; RODRÍGUEZ ALMEIDA, F.A.; PRIETO, C.; MOLIN DOMÍNGUEZ, N.I. 1998. Calidad de la canal y de la carne de borregos Pelibuey castrados. Revista Mexicana de Ciencias Pecuarias. 36(3):225-232.

19. MAHECHA, L.; ROSALES, M. 2005. Valor nutricional del follaje de botón de oro (T*ithonia diversifolia*(Helmsl.) Gray, en la producción animal en el trópico. Livestock Research for Rural Development. 17(9):100.

20. MEDINA, R.; SÁNCHEZ, A. 2006. Efecto de la suplementación con follaje de Leucaena leucocephala sobre la ganancia de peso de ovinos desparasitados y no desparasitados contra estrongílidos digestivos. Zootecnia Tropical. 24(1):55-68.

21. NATIONAL RESEARCH COUNCIL - NRC. 2006. Mineral Tolerance of Animals. Segunda edición. The National Academies Press. 510p. https://doi.org/10.17226/11309

22. NIELSEN, S. 1994. Introduction to the chemical analysis of foods. ed. Jones and Bartlett Publishers. U.S.A. 530p.

23. O'SULLIVAN, M.G.; BYRNE, D.V.; MARTENS, H.; GIDSKEHAUG, L.H.; ANDERSEN, H.J.; MARTENS, M. 2003. Evaluation of pork colour: prediction of visual sensory quality of meat from instrumental and computer vision methods of colour analysis. Meat science. 65(2):909-918. https://doi.org/10.1016/S0309-1740(02)00298-X

24. RAHMAN, A.; REHMAN, M.; GADAHI, J.A.; SAMO, M.T. 2012. Studies on the evaluation of moisture and ash content in Kamori, Pateri and Tapri goat meat. International Journal for Agro Veterinary and Medical Sciences. 6(1):62-68.

25. RÍOS, C.I. 2002. Usos, manejo y producción de Botón de Oro, *Tithonia diversifolia* (Hemsl) Gray. In: Ospina, S.; Murgueitio, E. (Eds.). Tres especies vegetales promisorias: nacedero (T*richanthera gigantea*) (H. & B) Nees.), botón de oro (*Tithonia diversifolia* (Hemsl) Gray) y bore (*Alocasia macrorrhiza* (Linneo) Schott). CIPAV, Cali. Colombia. p.211-311.

26. RODRIGUES, G.H.; SUNSIN, I.; VAZ PIRES, A.; QUIRINO MENDES, C.; SHIBATA URANO, F.; CONTRERAS CASTILLO, C.J. 2008. Polpa citrica para cordeiros em confinamento: características de carcaca e qualidade da carne. Revista Brasileira de Zootecnia. 37(10):25-27. https://doi.org/10.1590/S1516-35982008001000022

27. ROSENVOLD, K.; WIKLUND, E. 2011. Retail colour display life of chilled lamb as affected by processing conditions and storage temperature. Meat Science. 88(3):354-360. https://doi.org/10.1016/j.meatsci.2011.01.006

28. SEBSIBE, A. 2008. Sheep and goat meat characteristics and quality. In: Yami, A.; Merkel, R.C. Sheep and Goat Production Handbook for Ethiopia. Ethiopian Sheep and Goats Productivity Improvement Program (ESGPIP), Addis Ababa, Ethiopia. p.323-328.

29. ULUKAN, H. 2011. Responses of cultivated plants and some preventive measures against climate change. International Journal of Agriculture & Biology. 13:292-296.

30. VALERO GASPAR, T.; RODRÍGUEZ ALONSO, P.; RUIZ MORENO, E.; ÁVILA TORRES, J.M. VARELA MOREIRAS, G. 2018. La alimentación española. Características nutricionales de los principales alimentos de nuestra dieta. Ministerio de Agricultura, Pesca y Alimentación. Fundación española de la nutrición. (España). p.654.

31. VAN SOEST, P.J.; WINE, R.H. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. Journal Association of Official Analytical Chemists. 50(1):50-55. https://doi.org/10.1093/jaoac/50.1.50

32. VARGAS VELÁZQUEZ, V.T.; PÉREZ HERNÁNDEZ, P.; LÓPEZ ORTIZ, S.; CASTILLO GALLEGOS, E.; CRUZ LAZO, C.; JARILLO RODRÍGUEZ, J. 2022. Producción y calidad nutritiva de *Tithonia diversifolia* (Hemsl.) A. Grey en tres épocas del año y su efecto en la preferencia por

ovinos Pelibuey. Revista Mexicana de Ciencias Pecuarias. 13(1):5906. https://doi.org/10.22319/rmcp.v13i1.5906

33. VARELA MOREIRAS, G.; AVILA TORRES, J.M.; CUADRADO VIVES, C.: DEL POZO DE LA CALLE, S.; RUIZ MORENO, E.; MOREIRAS TUNY, O. 2009. Evaluación de patrones de consumo alimentario y factores relacionados en grupo de población emergentes: Inmigrantes. Ministerio de Medio Ambiente Rural y Medio Rural y Marino. Madrid. p.102.

34. ZHANG,S.X.;FAROUK,M.M.;YOUNG,O.A.;WIELICZKO, K.J.; PODMORE, C. 2005. Functional stability of frozen normal and high pH beef. Meat Science. 69(4):765-772. https://doi.org/10.1016/j.meatsci.2004.11.009