Acta Scientiarum. Animal Sciences
ISSN: 1806-2636
ISSN: 1807-8672
Editora da Universidade Estadual de Maringá - EDUEM

Oliveira, Liberato Lins de; Maior, Rinaldo José de Souto; Cavalcanti, Nathallia de Medeiros; Cardoso, Daniel Barros; Morais, Jasiel Santos de; Magalhães, André Luiz Rodrigues; Melo, Airon Aparecido Silva de; Silva, Dulciene Karla de Andrade

Native legumes and spineless cactus in supplementation of goats grazing in Caatinga rangeland: intake, performance, carcass characteristics, and meat quality

Acta Scientiarum. Animal Sciences, vol. 44, e56445, 2022
Editora da Universidade Estadual de Maringá - EDUEM

DOI: https://doi.org/10.4025/actascianimsci.v44i1.56445

Available in: https://www.redalyc.org/articulo.oa?id=303171455045

How to cite
Complete issue
More information about this article
Journal's webpage in redalyc.org

Scientific Information System Redalyc
Network of Scientific Journals from Latin America and the Caribbean, Spain and Portugal
Project academic non-profit, developed under the open access initiative

Acta Scientiarum
http://periodicos.uem.br/ojs/acta
ISSN on-line: 1807-8672
Doi: 10.4025/actascianimsci.v44i1.56445
CC BY

Native legumes and spineless cactus in supplementation of goats grazing in Caatinga rangeland: intake, performance, carcass characteristics, and meat quality

Liberato Lins de Oliveira[1], Rinaldo José de Souto Maior Junior[2], Nathallia de Medeiros Cavalcanti[1], Daniel Barros Cardoso[1*], Jasiel Santos de Morais[3], André Luiz Rodrigues Magalhães[1], Airon Aparecido Silva de Melo[1] and Dulciene Karla de Andrade Silva[1]

[1]Departamento de Zootecnia, Universidade Federal do Agreste de Pernambuco, Avenida Bom Pastor, s/n, 55292-270, Garanhuns, Pernambuco, Brazil. [2]Instituto Federal de Educação, Ciência e Tecnologia de Alagoas, Santana do Ipanema Alagoas, Brazil. [3]Departamento de Zootecnia, Universidade Federal Rural de Pernambuco, Recife, Brazil. *Author for correspondence. E-mail: daniel.cardosozootecnista@gmail.com

ABSTRACT: The study evaluated the performance, carcass characteristics, tissue composition, and meat quality of goats raised on pasture in the Caatinga rangeland supplemented with Leucena (*Leucaena leucocephala*) and Sabiá (*Mimosa caesapiniifolia*) hays associated or not with spineless cactus (*Nopalea cochenillifera*), and without supplementation. Thirty male castrated goats, no defined breed, with an average body weight of 15.5 kg ± 0.64 were used, distributed in a randomized block design, according to the initial weight of the animals. The experimental period lasted 105 days. The highest intake of DM, OM and CP occurred in the animals supplemented with Leucena hay associated or not with spineless cactus. The intake of NDF was higher (p <0.05) for animals fed only with Leucena and Sabiá hays. The highest intake of TDN was observed for diets, only grazing, and hays associated with spineless cactus. The daily weight gain for goats fed with Leucena hay and spineless cactus was 68.5% higher (p <0.05) than on grazing alone. Consequently, they obtained the highest (p <0.05) weights and yields of carcasses, shoulder, loin, and leg cuts, conformation and finishing scores, leg muscle index, and % fat in the leg of goats. The meat quality did not differ. The supplementation with Leucena hay associated with spineless cactus improves performance, weights, and yields of the carcass, commercial cuts, leg muscle of goats grazing in the Caatinga rangeland.

Keywords: semiarid biome; goats; food supplement; LMI.

Received on October 29, 2020.
Accepted on June 26, 2021.

Introduction

The Caatinga biome is exclusive to the semiarid region of Northeast Brazil, which currently occupies an area of 844,453 km^2 (Brasil, 2018). It is the basic feeding of small ruminants, characterized by a large diversity of herbs, shrubs, and trees that are very exuberant during the 4 months rainfall season (Fonteles et al., 2018). Among other uses it is the alternative medicine using its fruits, bark and roots; the exploration of natural resources, and sustenance for local populations (Silva et al., 2016). The biomass available for grazing animals varies according to the time of year and the amount of manipulation (Mota et al., 2019; Pinto Filho et al., 2019).

In this region, goat meat production is traditionally based on the use of Caatinga rangeland and thus limited by the large seasonal variations in the amount and quality of natural feed sources (Fonteles et al., 2018). The meat market for small ruminants in Brazil has expanded significantly in recent years, especially in the Northeast, but compared to other countries, the *per capita* consumption is still considered low. Therefore, it is necessary to make improvements in production systems, with the use of animals adapted to the conditions of the semiarid, improvements in nutritional management to cope with the drought through technologies such as silage and hay production.

Among the native species of this biome, Leucena (*Leucaena leucocephala* (Lam). de Wit) and Sabiá (*Mimosa caesapiniifolia* Benth) show potential to be used in the feeding of ruminants especially as a source of crude protein with an average value of 242 and 121 g kg^{-1} of DM, respectively (Silva, Melo, Rêgo, Lima, & Aguiar, 2011; Santos et al., 2017), serving as supplementary food during periods of drought. Also, energy is the main limitation of Caatinga vegetation during periods of drought. Thus, associated with these legumes, spineless cactus can be used, which has high values of total carbohydrates and non-fibrous carbohydrates (Siqueira et al., 2017; Maciel et al., 2019). In productive terms, one hectare of spineless cactus is capable of keeping 105 to 1,182 goats per year, depending on environmental conditions and the cultivar used (Edvan et al., 2020).

The supplementation strategies to meet the nutritional requirements of goats are extremely important to maintain the weight gain in times of forage scarcity reducing the age of slaughtering. The feed supplementation improves carcass characteristics and meat quality of goats grazing in the Caatinga (Souza et al., 2015; Silva, Guim, Santos, Maciel, & Soares, 2015; Silva et al., 2020). Thus, the aim was to evaluate the effect of supplementation with Leucena hay and Sabiá hay in association or not with spineless cactus on intake, performance, quantitative carcass characteristics, tissue composition, and meat quality of goat grazing in the Caatinga rangeland.

Material and methods

The handling and care of the animals were carried out according to the guidelines and recommendations of the UFRPE Animal Ethics Commission (CEUA), under license number (104/2014).

The experiment was carried out at the Rural Technology Development and Dissemination Station of Sertão Alagoano, located in Piranhas-AL, whose geographical position coordinates are Latitude: 09° 37' 25 "South and Longitude: 37° 45' 24" W, at 88 m above sea level in a Caatinga ecosystem with a tropical semiarid climate.

Thirty male castrated goats of no defined breed with an average body weight of 15.5 kg ± 0.64, were distributed in blocks according to body weight. The animals were treated against endo and ectoparasites (Ivomec® 1%, Merial, São Paulo, Brazil), and underwent adaptation to the environment and management for 15 days.

The experimental period lasted 105 days, with five subperiods of 21 days for weighing and supplementation adjustment. The animals were allocated to five treatments: grazing without supplementation (G); grazing and supplemented with Leucena hay (*Leucaena leucocephala* (Lam). de Wit) (LH); grazing and supplemented with Leucena hay associated with spineless cactus (*Nopalea cochenillifera* - Salm Dyck) (LH + SC); grazing and supplemented with Sabiá hay (*Mimosa caesalpiniaefolia* Benth) (SH); and grazing and supplemented with Sabiá hay associated with spineless cactus (SH + SC). Supplements associated with spineless cactus were provided at a 50:50 ratio based on a dry matter (DM) (Table 1).

Table 1. Chemical composition of the ingredients.

Ingredients	Extrusa	Spineless cactus	Leucena Hay	Sabiá hay
Dry matter (g kg^{-1} de NM)	141.0	137.6	842.0	878.4
Organic matter (g kg^{-1})	894.0	882.5	896.1	944.9
Crude protein (g kg^{-1})	171.0	32.6	276	216.5
Ether extract (g kg^{-1})	-	16.9	30	42.5
Neutral detergent fiber (g kg^{-1})	624.0	213	481.1	465.4
Total carbohydrates (g kg^{-1})	723.0	833.0	590.1	685.9
Non-fibrous carbohydrates (g kg^{-1})	99.0	620.0	109.0	220.5

NM = natural matter.

The animals were kept under continuous stocking (0.81 animals per hectare), in an area corresponding to 37 hectares of Caatinga rangeland. The plants available in the area, and that the animals ingested were: *Croton heliotropiifolius* ‘velame’, *Neoglaziovia variegata* ‘caroá’, *Caesalpinea bracteosa* ‘catingueira’, *Aspidosperma pyrifolium* ‘pereiro’, *Bromelia laciniosa* ‘macambira’, *Mimosa tenuiflora* ‘jurema preta’, *Melochia tomentosa* ‘capa bode’, *Hypolytrum pungens* ‘capim navalha’, *Prosopis juliflora* ‘algaroba’ and burlap. During the grazing period (7:30 to 15:00 hours), the animals had free access to water and mineral mix. At the end of the afternoon (15:00 hours), the animals were collected and allocated in sheds with individual pens (1.2 m2), provided with feeders, drinking fountains and mineral mix freely. Animals from supplementation treatments were fed 1% of body weight according to the treatments.

The samples of feed, feces, and leftovers were analyzed for the composition of dry matter (DM, method 934.01), ash (method 942.05), organic matter (MO, method 930.05), crude protein (CP, Kjeldahl N×6.25, method 981.10), and ether extract (EE, method 920.39) according to the methodology described by Association of Official Analytical Chemistry [AOAC] (1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to the methodology of Van Soest, Robertson, and Lewis (1991). The NDF was corrected for ash and protein according to methodologies described by Mertens (2002) and Licitra, Hernandez, and Van Soest (1996), respectively.

Total carbohydrates (TC) were determined according to Sniffen, O'Connor, and Van Soest (1992), TC: 100 - (%CP + %EE + %Ash); non-fibrous carbohydrates: NFC = 100 - (%CP + %NDF - NDFap + %EE + %Ash), where NDFap is the neutral detergent fiber corrected for ash and protein. Total digestible nutrients (TDN) were calculated according to Weiss, Conrad, and Pierre (1999): TDN = [DCP + DNFC + DNDFap + (DEE × 2.25)] where, DCP = digestible crude protein, DNFC = digestible non-fibrous carbohydrates, DNDFap = digestible neutral detergent fiber and DEE = digestible ether extract.

For the thorough pasture dry matter (DM) intake, fecal dry matter production (FDMP) was used applying the external indicator LIPE®. It was used 250 mg of LIPE® in single daily oral doses during the last seven days of each subperiod (16th to 21st day). The Feces was collected for five consecutive days directly from the rectal ampoule before animals had access to pasture (Saliba et al., 2015). The fecal samples were pre-dried in a 55ºC oven for 72 hours and then ground in a Willey mill on 2 mm sieves. After that, the fecal samples were sent to the Animal Nutrition Laboratory of the Federal University of Minas Gerais (UFMG), to estimate the FDMP.

To determine the extrusion collection in the pasture, five rumen fistulated male adult goats were used. In the morning, the fistulated animals had their ruminal contents emptied and stored in plastic buckets, and then these animals were released into the experimental area for one hour. After that time, the ruminal content consumed in the pasture by the animals was collected, separated, identified, and stored in a freezer at - 20°C. The initial content was returned to the rumen of the respective animals which were released on the pasture again.

At the end of the experiment, the animals were fasted on solids for 16 hours to determine slaughter body weight (SBW) and were then numb following humanized slaughter recommendations (Brasil, 2000). The animals were slaughtered on the 105th day of the experimental period. The hot carcass weight (HCW) of the animals was obtained after bleeding, skinning, evisceration, and removal of the head, feet, and genitals.

After the head and feet were removed, the carcasses were cooled in a cold chamber for 24 hours at 4°C, and then weighed to determine the cold carcass weight (CCW). With data, hot carcass yield (HCY) and cold carcass yield (CCY) were calculated based on carcass weight in relation to slaughter body weight.

The subcutaneous fat thickness fat (SFT) measured in the *Longissimus dorsi* muscle at approximately 2/3 of the muscle length was also measured. Perirenal fat was subjectively evaluated using a scale from 1 to 3, according to the methodology proposed by Cezar and Souza (2007).

Carcass morphometric characteristics were measured as described by Cezar and Souza (2007). Measurements included internal and external carcass lengths, leg length, hind width, thoracic width, and thoracic circumference.

Blood was collected and weighed, and the gastrointestinal tract was individually weighed, filled, and empty to determine the weight of gastrointestinal content. Empty body weight (EBW) was calculated as the difference between slaughter body weight and gastrointestinal tract content (GITC). It was also calculated the true yield (TY) = CCW/GITC x 100. The weight of organs and viscera (liver, kidneys, respiratory system, tongue, heart, pancreas, and intestines) were summed to determine non-carcass components.

The carcasses were divided longitudinally along the midline into two symmetrical parts, and the left side was divided into six commercial parts (neck, shoulder, ribs, saw, loin, and leg) and weighed individually. The yields of each cut were determined in relation to the cold carcass weight, expressed as a percentage.

The left leg of the animals was dissected to determine tissue composition according to the methodology described by Brown and Williams (1979), for the following tissue components: subcutaneous fat, intermuscular fat, total muscles, bones, and other tissues. These data served to calculate the leg muscularity index (LMI) according to Purchas, Davies, and Abdullah (1991): LMI = √(WM5/FL)/FL, where the WM5, is the weight of the five main muscles that compose the femur (*Biceps femoris*, *Semimembranosus*, *Semitendinosus*, *Adductor femoris*, and *Quadriceps femoris*) expressed in g, and FL = femur length, in cm.

The *Longissimus lumborum* (steaks) muscle samples were weighed before and after thawing at 4 ± 1.0ºC for 24 hours to determine the weight loss of thawing in a standard refrigerator. The shear force (SF) was obtained in two steaks (2.5 cm2) in duplicate, the steaks were baked in a preheated oven with an internal temperature of 71 ± 1.0ºC (monitored by K-type thermocouples inserted in the geometric center of the samples) and reading with the digital reader (TENMARS, model TM-361). *Longissimus lumborum* muscle samples were cut transversely to the direction of the muscle fibers to determine SF using the Warner-Bratzler shear apparatus (G-R MANUFACTURING CO., Model 3000), expressed in kgf.

The meat color was determined according to the CIELAB system with the aid of a colorimeter (KONICA MINOLTA CR10), which were evaluated: *L** (lightness), a* (redness), and b* (yellowness), in triplicate with three readings at strategic points on steaks exposed to air for 30 minutes at 4 ± 1.0°C, with the *L. lumborum* cut performed transversely to the muscle fibers (Wheeler, Cundiff, & Koch, 1995).

The data obtained were analyzed by analysis of variance (ANOVA), using the PROC GLM procedure of Statistical Analysis System [SAS] 9.3 (2015) statistical package according to the following model (Equation 1):

$$Yijk = \mu + \tau i + \beta j + \tau\beta ij + \varepsilon ijk \quad (1)$$

Where, *Yijk* = observed value *k* in the experimental unit receiving treatment *i*, repetition *j*; *μ* = general average common to all observations; *τi* = effect of treatment *i*; *βj* = effect of block *j*; *τβij* = interaction effect treatment *i* and block *j*; *εijk* = random error. The Tukey test, at 5% probability, was used to compare the averages between treatments.

Results and discussion

The dry matter (DM), and organic matter (OM) intakes were higher (p <0.05) for animals supplemented with Leucena hay associated or not with spineless cactus, with increases of 26.50 and 28.48% in the intake of DM and OM in the animals' diet, respectively (Table 2). In previous studies (Souza et al., 2015; Silva et al., 2016; Silva et al., 2020) show that food supplementation maximizes the intake of DM of goats raised on pasture in the Caatinga. Although the supplements increase the intake of DM and OM, the Sabiá hay caused low acceptability by the animals, even associated with the spineless cactus. According to Alves, Beelen, Medeiros, Gonzaga Neto, and Beelen (2011), Sabiá hay causes an unpleasant taste in the animal's mouth, limiting food intake.

Table 2. Nutrient intake of the supplement by goats grazing in the Caatinga and supplemented with native legumes hays and spineless cactus.

Item	Treatments					SEM	p-value
	Grazing	LH	LH+SC	SH	SH+SC		
Intake (g day^{-1})							
Dry matter	386.6c	463.4ab	489.0a	446.9b	447.4b	5.57	<0.001
Organic matter	342.9c	413.3ab	440.6a	393.9b	400.6b	5.18	<0.001
Crude protein	51.18b	73.49a	66.70a	56.10b	55.35b	1.05	<0.001
Ether extract	15.01	17.04	16.39	17.14	16.71	0.33	0.274
NDF	231.5b	297.7a	237.2b	251.2ab	245.0b	6.00	0.002
TC	276.7b	322.7a	357.5a	320.6a	328.5a	4.73	0.003
NFC	45.21b	25.07c	120.31a	69.46ab	83.54a	5.97	0.001
TDN	293.4c	344.0ab	362.2a	327.9b	328.2b	4.65	0.015
TDN*	758.9a	742.4ab	740.7ab	733.8b	733.7b	2.56	0.014

SEM = standard error of the mean; NDF = neutral detergent fiber; *TDN = total digestible nutrients (g kg^{-1} of DM intake); TC = total carbohydrates; NFC = non-fibrous carbohydrates; LH = Leucena hay; LH+SC = Leucena hay + spineless cactus; SH = Sabiá hay; SH + SC = Sabiá hay + spineless cactus. Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

The intake of crude protein (CP) was higher (p <0.05; Table 2) for animals supplemented with Leucena hay, or associated with spineless cactus, followed by animals fed supplements with only Sabiá hay, or associated with spineless cactus. These intakes were probably influenced by the chemical composition of these foods, with a higher crude protein value when compared to pasture (Table 1). However, despite the low protein content of the spineless cactus (32.6 g kg^{-1} DM), the intake of CP was counterbalanced by the association with Leucena hay (276 g CP kg^{-1} DM), as well as by the increase in the DM intake. The low acceptability of Sabiá hay may explain the similarity of CP intake between treatments with Sabiá hay, and Sabiá hay associated with spineless cactus, and in the exclusive pasture (Table 2), while the intake of ether extract (EE) that did not differ (p >0.05, Table 2).

The intake of neutral detergent fiber (NDF) was lower (p <0.05) for goats fed only on pasture, and for those supplemented with Leucena and Sabiá hay associated with the spineless cactus. A higher intake of total carbohydrates (TC) and non-fibrous carbohydrates (NFC) was observed on goats fed with hays of native legumes associated with the spineless cactus (Table 2). That may have occurred because the spineless cactus presents low NDF and high NFC contents compared to Leucena and Sabiá hays (Table 1), which reduced the amount of fiber ingested. Also, the lower amount of NDF ingested in the Leucena hay associated with spineless cactus treatment explains the higher DM intake compared to the other treatments. Regarding animals fed only with pasture, the lower value of NDF intake compared to those supplemented with hay may be related to the selection capacity of these animals. Consequently, the total digestible nutrients (TDN) intake (g day^{-1}) were influenced by the treatments (p <0.05), with higher values observed for animals fed with Leucena hay, with or without spineless cactus (Table 2).

The performance was influenced by the treatments (p <0.05). The observed average daily gain (ADG) was between 13.42 to 42.84 g day^{-1} of the animals. Leucena hay associated with spineless cactus showed a daily weight gain 68.5% higher (p <0.05) than on animals in the exclusive pasture (p <0.05, Table 3).

Table 3. Carcass weights and yields of grazing goats in the Caatinga and supplemented with native legumes hays and spineless cactus.

Item	Treatments					SEM	p-value
	Grazing	LH	LH+SC	SH	SH+SC		
Body weight at slaughter (kg)	17.31	17.83	18.29	15.88	17.00	0.46	0.150
Empty body weight (kg)	13.42ab	14.42a	15.37a	12.22b	13.75ab	0.40	0.017
Average daily gain (g day^{-1})	13.50b	27.00ab	42.84a	21.03ab	33.29ab	3.44	0.027
Hot carcass weight (kg)	7.29b	7.60ab	8.49a	6.70b	7.38ab	0.34	0.022
Cold carcass weight (kg)	6.99ab	7.17ab	8.20a	6.31b	7.00ab	0.34	0.012
Hot carcass yield (%)	42.07b	42.70b	46.43a	43.25b	43.32b	0.42	0.001
Cold carcass yield (%)	38.99b	40.28b	43.83a	40.82b	40.99b	1.58	0.001
Biological yield (%)	52.4	52.74	54.91	54.67	53.6	0.39	0.100
Cooling losses (%)	5.64ab	5.6b	5.24b	5.71ab	6.31a	1.66	0.006
SFT (mm)	0.32	0.30	0.31	0.19	0.40	0.04	0.182
Conformation	1.50b	1.83ab	2.5a	1.25b	1.50b	0.14	0.020
Finishing	1.25b	1.67ab	2.33a	1.5ab	1.5ab	0.13	0.023
Perirenal fat	1.00b	1.17b	2.17a	1.00b	1.63ab	0.12	0.002
Color of meat	2.25	2.33	2.50	2.50	2.50	0.14	0.383

SEM = standard error of the mean; LH = Leucena hay; LH+SC = Leucena hay + spineless cactus; SH = Sabiá hay; SH + SC = Sabiá hay + spineless cactus. SFT = subcutaneous fat thickness. Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

The difference of performance between treatments can be related to food ingestion, considering that the animals fed with Leucena hay associated with spineless cactus showed the highest averages of DM, OM, CP and TDN (Table 2), improving the supply of nutrients, mainly due to the synchronism between the crude protein of Leucena hay and energy of the spineless cactus for the population of ruminal microorganisms, thus improving the performance with values of 42.84 g day^{-1} when compared with non-supplemented animals (13.50 g day^{-1}). On the other hand, the latter, fed only on plants available in the Caatinga area during the daily grazing time, suffered a direct effect on nutrients intake and the synthesis of body tissues, and consequently on the ADG. However, the amount of TDN and CP ingested by the animals of all treatments would meet the nutritional requirements for an ADG of 50 to 80 g day^{-1}, according to National Research Council [NRC] (2007) recommendations. But this may not have occurred due to the indigestible fraction of the CP of the hays used (Santos et al., 2017), as well as the low weight gain potential of the animals studied. It can be inferred that the Caatinga pasture can keep the animals gaining body weight, but it is necessary additional 73 days to reach the weight of the animals supplemented with Leucena hay associated with spineless cactus. Thus, that supplementation can maximize the ADG.

Consequently, corroborating the performance, which were influenced by DM and nutrient intakes, the empty body weight (EBW), hot carcass weight (HCW), and cold carcass weight (CCW) increased (p <0.05) by 25.78, 26.72, and 29.95%, respectively, with the supplementation of Leucena hay in association with spineless cactus compared to Sabiá hay. Although, the body weight at slaughter (BWS) is not influenced (p >0.05, Table 3), the hot and cold carcass yields, expressed in %, followed the results found for CCW and HCW with the Leucena hay associated with spineless cactus (Table 3). The biological yield showed no difference between treatments (p >0.05), which on average ranged between 52.4 and 54.91%. This result is within the average for goats, which varies between 35 and 60% according to Hashimoto et al. (2007).

The conformation and finishing of the carcasses, as well as the perirenal fat scores differed between treatments (p <0.05), with higher values observed for the carcasses of animals supplemented with Leucena and Sabiá hay and associated with spineless cactus. However, the subcutaneous fat thickness was not influenced by treatments (p >0.05, Table 3). This best average for conformation in relation to the other treatments can be considered satisfactory for animals grazing in a semiarid region, which has the characteristic of traveling great distances in search of food, thus generating very high energy expenditure. Such characteristic can be observed by the results of the treatments to which the animals remained only on grazing and obtained lowest scores. Similar results were found by Bezerra et al. (2012) for goats supplemented in Caatinga vegetation with soybean meal and spineless cactus with convex conformation, but with scores between 1 and 5. The degree of conformation of the carcass of small ruminants must present profiles between concave to hyper-convex, depending on the depth of muscle mass deposited in the bone base (Cezar & Sousa, 2007), however, in goats the carcass conformation scores start from concave to convex (1 - 3) due to their physiological characteristics of depositing less muscle mass than sheep.

Following the same trend as the conformation, the finishing of the carcass of animals that were supplemented with Leucena hay associated with spineless cactus were those that obtained the highest values (2.23), despite the carcass being considered by the score as lean. However, fat thickness did not differ (p >0.05) between treatments with an average value of 0.3 mm. Silva et al. (2014) stated that the reduced deposition of subcutaneous fat is a characteristic of the goat species. Also, the deposition of body fat is greater around the internal organs because it is a characteristic peculiar to goats (Brand, Van Der Merwe, Swart, & Hoffman, 2019), especially in the no defined breed, due to adaptive issues throughout its evolution. The data on the amount of pelvic-renal fat can be correlated in a certain way, with the amount of fat present in the carcass (Cezar & Sousa, 2007). In the present work, it is clear that there is a relationship between the results of finishing the carcass with the perirenal fat score, with animals supplemented with Leucena hay in association with spineless cactus that obtained the best results, being directly related to the intake of DM and nutrients, mainly TDN intake. This score value (2.16) is considered a deposition of average perirenal fat, which is the most common condition for goats supplemented in the Caatinga.

The internal carcass length and thoracic width were influenced by diets (p <0.05; Table 4).

Table 4. Morphometric measurements of the carcass (cm) of grazing goats in the Caatinga plus supplemented with native legumes hays and spineless cactus.

Item	Treatments					SEM	p-value
	Grazing	LH	LH+SC	SH	SH+SC		
External carcass length	44.94	45.33	45.58	44.88	44.31	0.49	0.012
Internal carcass length	47.75b	52.83a	53.83a	51.00ab	51.94a	0.62	0.002
Hind width	11.00	11.08	11.58	11.00	11.13	0.11	0.057
Hind perimeter	41.38	42.50	43.79	40.31	42.94	0.48	0.277
Thoracic width	15.75b	16.00b	17.42a	15.63b	15.08b	0.20	0.001
Thoracic depth	28.29	24.83	24.17	24.38	24.67	0.18	0.828
Thoracic perimeter	56.25	57.17	57.25	55.25	55.88	0.54	0.718
Leg length	34.00	36.50	35.79	36.50	35.81	0.66	0.676
Leg perimeter	26.38	27.00	27.83	25.88	25.50	0.34	0.130

SEM = standard error of the mean; LH = Leucena hay; LH+SC = Leucena hay + spineless cactus; SH = Sabiá hay; SH + SC = Sabiá hay + spineless cactus. Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

For internal carcass length, the highest values were obtained in the carcasses of animals supplemented with Leucena and Sabiá hay, associated or not with spineless cactus. However, thoracic width was higher for carcasses of goats fed with Leucena hay associated with spineless cactus (Table 4), for they were influenced by higher energy and protein intake provided by food supplementation.

However, these results had no influence on the neck, saw, and rib cuts (P>0.05); likewise, the respective yields, expressed in%, were also not affected by the treatments (p >0.05; Table 5).

While the commercial cuts of the shoulder, loin, and leg differed (p <0.05) between treatments. As well as the cold carcass weight, the cut weight of the animals in the Leucena hay associated with spineless cactus treatment was higher than the other treatments. Regarding the cut yields, only the shoulder, loin, and leg differed (p <0.05; Table 5). Bezerra et al. (2012) working with no defined breed goats reported that supplementation with spineless cactus and soybean meal influenced neck and loin cuts. Also, Silva et al. (2014) did not observe the effects of treatments of commercial cuts of crossbred goats supplemented in a pasture in the Caatinga rangeland.

The animals supplemented with Leucena hay associated with spineless cactus obtained better results (p <0.05) for the weight of the reconstituted leg than the animals of the other experimental groups (Table 6). This result is linked to the fact that the animals of the same treatment obtained higher DM, NFC and TDN average intake, resulting in a greater supply of nutrients for the synthesis of new muscle tissues.

Table 5. Weight and yield of commercial cuts in the carcass of grazing goats in the Caatinga plus supplemented with native legumes hays and spineless cactus.

Item	Treatments					SEM	p-value
	Grazing	LH	LH+SC	SH	SH+SC		
Weight (kg)							
Neck	0.55	0.62	0.75	0.55	0.57	0.04	0.097
Saw	0.56	0.67	0.70	0.47	0.61	0.04	0.439
Ribs	0.89	0.85	1.19	0.83	1.04	0.08	0.101
Shoulder	1.28b	1.40ab	1.74a	1.14b	1.38ab	0.09	0.017
Loin	0.60b	0.71ab	0.89a	0.49b	0.65b	0.05	0.003
Leg	1.91b	2.10ab	2.66a	1.62b	2.01ab	0.14	0.011
Yield (%)							
Neck	7.82	8.42	9.06	8.59	8.03	0.44	0.412
Saw	7.91	8.39	8.91	7.35	8.54	0.47	0.335
Ribs	12.72	12.5	14.83	12.96	13.97	0.74	0.562
Shoulder	18.20b	19.07ab	21.70a	17.81b	18.81b	1.00	0.006
Loin	8.46bc	9.65ab	10.88a	7.61c	8.99bc	0.51	0.001
Leg	27.15b	28.67ab	32.83a	25.17b	27.94b	1.49	0.003

SEM = standard error of the mean; LH = Leucena hay; LH+SC = Leucena hay + spineless cactus; SH = Sabiá hay; SH + SC = Sabiá hay + spineless cactus. Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

Table 6. Tissue composition of the leg and physical-chemical (*Longissimus lumborum*) muscle of grazing goats in the Caatinga plus supplemented with native legumes hays and spineless cactus.

Item	Treatments					SEM	p-value
	Grazing	LH	LH+SC	SH	SH+SC		
Leg (kg)	1.061b	1.129b	1.309a	1.10b	1.12b	0.032	0.001
LMI	0.29b	0.305ab	0.335a	0.27b	0.306ab	0.005	0.023
Fat (%)	2.95b	3.35ab	4.89a	3.06b	3.71ab	0.625	0.016
Bones (%)	28.68	26.57	24.55	27.37	26.42	0.474	0.899
Muscle (%)	63.96	66.02	66.09	62.96	64.64	0.510	0.323
Other tissues (%)	4.40	1.30	4.05	6.96	4.96	0.910	0.456
pH 0 hours	7.08	6.82	6.65	7.11	6.64	0.06	0.084
pH 24 hours	5.87	5.83	5.88	5.79	5.85	0.03	0.898
Shear force (Kgf)	3.88	3.57	2.92	3.8	3.46	0.17	0.503
Cooking losses (%)	5.37	5.78	6.38	5.19	4.84	0.21	0.193
*L** (lightness)	36.47	40.55	40.22	36.99	37.29	0.54	0.050
a* (redness)	11.14	11.69	11.72	13.3	12.1	0.25	0.366
b* (yellowness)	6.30	7.40	7.74	8.45	7.05	0.23	0.105

LMI = leg muscularity index. Averages in rows followed by different letters are statistically different by the Tukey test at 5% probability.

The leg muscularity index (LMI), and proportion of fat of the animals of the Leucena hay associated with spineless cactus treatment was similar to those fed only with Leucena hay and Sabiá hay in association with spineless cactus treatment, differing from the other treatments (p <0.05; Table 6). The leg muscularity index is a measure that seeks to assess the number of muscles in the leg (Silva Sobrinho, Purchas, Kadim, & Yamamoto, 2005). Therefore, the higher the LMI, the greater the amount of muscle in the leg, which makes it easier to compare animals with lighter bones or heavier muscles. While the proportions of bone, muscle, and other tissues in relation to the weight of the reconstituted leg did not differ between treatments (p >0.05) (Table 6).

The treatments did not influence (p >0.05) the physical-chemical characteristics evaluated in the meat. The average values of the *post mortem* pH at 0 and 24 hours were 6.85 and 5.81, respectively. Final pH values for the goat species grazed in the Caatinga were found by Silva et al. (2015), and Silva et al. (2020). While the mean values obtained for the color of meat were 38.38 for L* (lightness), 11.75 for a* (redness), and 7.21 for b* (yellowness) (Table 6). The color of the meat was probably not influenced because the *post mortem* pH did not differ; it has a direct effect on the color of the fresh meat and the meat's ability to maintain its water content and texture (Hughes, Oiseth, Purslow, & Warner, 2014). These results are similar to those found by Mushi, Thomassen, Kifaro, Sorheim., & Adnoy (2008), Xazela, Chimonyo, Muchenje, and Marume (2012), Silva et al. (2015), and Silva et al. (2020) with L* between 34.6 and 41.8, a* between 8.64 and 15.1, and b* between 6.02 and 7.68.

In this study, supplementation also did not influence (p >0.05) the cooking loss and shear force, which had an average of 32.43% and 3.49 kgf cm^{-2} between treatments, respectively (Table 6). The cooking loss is a measure of quality, which according to Monte, Gonsalves, Villarroel, and Cavalcante (2012) is associated with meat yield at the time of consumption, being a characteristic influenced by the water holding capacity in the meat structures. While for shear force, the results obtained, it can be said that the meat of these animals can be considered soft, according to the classification of Cezar and Souza (2007).

Conclusion

It is recommended to supplement 1% of body weight for goats grazing in the Caatinga with the Leucena hay in association or not with the spineless cactus, as it improves the productive performance, carcass weights, leg muscle, and commercial cuts.

Acknowledgements

The authors express gratitude to the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superio*r (CAPES) for granting a postgraduate scholarship (Master degree) and to the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPq) for funding this research.

References

Association of Official Analytical Chemistry [AOAC]. (1990). *Official methods of analysis*. Arlington, VA: AOAC International.

Alves, A. R., Beelen, P. M. G., Medeiros, A. N., Gonzaga Neto, S., & Beelen, R.N. (2011). Consumo e digestibilidade do feno de sabiá por caprinos e ovinos suplementados com polietilenoglicol. *Revista Caatinga, 24*(2), 152-157.

Bezerra, S. B. L., Véras, A. S. C., Silva, D. K. A., Ferreira, M. A., Pereira, K. P., Santos, G. R. A., ... Almeida, O. C. (2012). Morphometry and carcass characteristics of goats submitted to grazing in the Caatinga. *Revista Brasileira de Zootecnia, 41*(1), 131-137. DOI: https://doi.org/10.1590/S1516-35982012000100020

Brand, T. S., Van Der Merwe, D. A., Swart, E., & Hoffman, L. C. (2019). The effect of finishing period and dietary energy content on the carcass characteristics of Boer goats. *Small Ruminant Research, 174*(1), 110-117. DOI: https://doi.org/10.1016/j.smallrumres.2019.03.012

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. (2000). *Instrução normativa n. 3; de 17 de Janeiro de 2000. Aprova o Regulamento técnico de métodos de insensibilização para o abate humanitário de animais de açougue*. Brasília, DF: Ministério da Agricultura, Pecuária e Abastecimento.

Brasil. Ministerio de Meio Ambiente. (2018). *Caatinga*. Retrieved from http://www.mma.gov.br/biomas/caatinga.

Brown, A. J. & Williams, D. R. (1979). *Sheep carcass evaluation: measurement of composition using a standardized butchery method*. Langford, UK: Agricultural Research Council; Meat Research Council.

Cezar, M. F., & Sousa, W. H. (2007). *Carcaças ovinas e caprinas – obtenção – avaliação – classificação*. Uberaba, MG: Editora Agropecuária Tropical.

Edvan, R. L., Mota, R. R. M., Dias-Silva, T. P., Nascimento, R. R., Sousa, S. V., Silva, A. L., ... Araújo, J. S. (2020). Resilience of cactus pear genotypes in a tropical semi-arid region subject to climatic cultivation restriction. *Nature*, 10(1), 10040. DOI: https://doi.org/10.1038/s41598-020-66972-0

Fonteles, N. L. O., Alves, S. P., Madruga, M. S., Queiroga, R. R. E., Andrade, A. P., Silva, D. S., ... Medeiros, A. N. (2018). Fatty acid composition of polar and neutral meat lipids of goats browsing in native pasture of Brazilian Semiarid. *Meat Science, 139*(1), 149-156. DOI: https://doi.org/10.1016/j.meatsci.2018.01.021

Hashimoto, J. H., Alcalde, C. R., Silva, K. T., Macedo, F. A. F., Mexia, A. A., Santello, G. A., ... Matsushita, M. (2007). Características de carcaça e da carne de caprinos Bôer x Saanen confinados recebendo rações com casca do grão de soja em substituição ao milho. *Revista Brasileira de Zootecnia, 36*(1), 165-173. DOI: https://doi.org/10.1590/S1516-35982007000100020

Hughes, J. M., Oiseth, S. K., Purslow, P. P., & Warner, R. D., 2014. A structural approach to understanding the interactions between colour, water-holding capacity and tenderness. *Meat Science. 98*(3), 520-532. DOI: https://doi.org/10.1016/j.meatsci.2014.05.022

Licitra, G., Hernandez, T. M., & Van Soest, P. J. (1996). Standardization of procedures for nitrogen fractionation of ruminant feed. *Animal Feed Science Technology, 57*(4), 347-358.

Maciel, L. P. A. A., Carvalho, F. F. R., Batista, Â. M. V., Guim, A., Maciel, M. V., Cardoso, D. B., & Lima Júnior, D. M. (2019). Intake, digestibility and metabolism in sheep fed with increasing levels of spineless cactus (*Nopalea cochenillifera* Salm-Dyck). *Tropical Animal Health and Production, 51*(1), 1717-1723. DOI: https://doi.org/10.1007/s11250-019-01868-4

Mertens, D. R. (2002). Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beaker or crucibles: collaborative study. *Journal of AOAC International, 85*(6), 1217-1240.

Monte, A. L. S., Gonsalves, H. R. O., Villarroel, A. B. S., Damaceno, M. N., & Cavalcante, A. B. D. (2012). Qualidade da carne de caprinos e ovinos: uma revisão. *Agropecuária Científica no Semi-Árido, 8*(3), 11-17.

Mota, N. S. O., Pereira Filho, J. M., Formiga, L. D. A. S., Silva, A. M. A., Cezar, M. F., Bakke, O. A., ... Bezerra, L. R. (2018). Comparison between lambs and goat kids meat production of animals fed Caatinga vegetation enriched with buffel (*Cenchrus ciliaris* L.) grass. *Semina: Ciências Agrárias, 39*(6), 2795-2806. DOI: https://doi.org/10.5433/1679-0359.2018v39n6p2795

Mushi, D. E., Thomassen, M. S., Kifaro, G. C., Sorheim., & Adnoy, T. (2008). Suitability of Norwegian short-tail lambs, Norwegian dairy goats and Cashmere goats for meat production – Carcass, meat, chemical and sensory characteristics. *Meat Science, 80*(3), 842-850.

National Research Council [NRC]. (2007). *Nutrient requirements of small ruminants: sheep, goats, cervids and New World camelids*. Washington, DC: National Academies Press.

Pinto Filho, J. S., Cunha, M. V., Souza, E. J. O., Santos, M. V. F., Lira, M. A., Moura, J. G., ... Silva, C. S. (2019). Performance, carcass features, and non-carcass components of sheep grazed on Caatinga rangeland managed with different forage allowances. *Small Ruminant Research, 174*(5), 103-109. DOI: https://doi.org/10.1016/j.smallrumres.2019.03.010

Purchas, R. W., Davies, A. S., & Abdullah, A. Y. (1991). An objective measure of muscularity changes with animal growth and differences between genetic lines of Southdown sheep. *Meat Science, 30*(1), 81-94. DOI: https://doi.org/10.1016/0309-1740(91)90037-Q

Saliba, E. O. S.; Faria, E. P., Rodriguez, N. M., Moreira, G. R., Sampaio, I. B. M., Saliba, J. S., ... Borges, A. L. C. (2015). Use of infrared spectroscopy to estimate fecal output with marker Lipe®. *International Journal of Food Science, Nutrition and Dietetics, 4*(9), 1-10. DOI: https://doi.org/10.19070/2326-3350-SI04001

Santos, K. C., Magalhães, A. L. R., Silva, D. K. A., Araújo, G. G. L., Fagundes, G. M., Ybarra, N. G., & Abdalla, A. L. (2017). Nutritional potential of forage species found in Brazilian Semiarid region. *Livestock Science, 195*(1), 118-124. DOI: https://doi.org/10.1016/j.livsci.2016.12.002

Statistical Analysis System [SAS]. (2015). *SAS/STAT User's guide, Version 9.3*. Cary, NC: SAS Institute Inc.

Silva Sobrinho, A. G., Purchas, R. W., Kadim, I. T., & Yamamoto, S. M. (2005). Musculosidade e composição da perna de ovinos de diferentes genótipos e idades ao abate. *Pesquisa Agropecuária Brasileira, 40*(11), 1129-1134.

Silva, D. C., Guim, A., Santos, G. R. A., Maciel, M. I. S., & Soares, L. F. P. (2015). Levels of feed supplementation on the qualitative aspects of meat from crossbred goats finished on caatinga. *Revista Ciência Agronômica, 46*(4), 855-864. DOI: https://doi.org/10.5935/1806-6690.20150074

Silva, D. C., Guim, A., Santos, G. R. A., Mesquita, F. L. T., Morais, N. A. P., Urbano, S. A., ... Lafayette, E. A. (2014). Níveis de suplementação sobre as características quantitativas da carcaça e composição tecidual do pernil de caprinos mestiços terminados na caatinga. *Revista Brasileira de Saúde e Produção Animal, 15*(3), 705-716.

Silva, D. C., Guim, A., Santos, G. R. A., Souza, E. J. O., Urbano, S. A., Mesquita, F. L. T., & Lafayette, E. A. (2016). Intake and digestibility of crossbred goats finished on caatinga grassland receiving feed supplementation during dry season. *Revista Brasileira de Saúde e Produção Animal, 17*(3), 484-496. DOI: https://doi.org/10.1590/S1519-99402016000300014

Silva, D. K. A., Cordeiro, F. S. B., Silva, E. C. L., Cardoso, D. B., Magalhães, A. L. R., Melo, A. A. S., ... Silva, E. T. (2020). Intake, performance, carcass traits and meat quality of goats grazing in the Caatinga rangeland. *Semina: Ciências Agrárias, 41*(5), 1639-1652. DOI: https://doi.org/10.5433/1679-0359.2020v41n5p1639

Silva, J. G. M., Melo, A. A. S., Rêgo, M. M. T., Lima, G. F. C., & Aguiar, E. M. (2011). Cactáceas nativas associadas a fenos de flor de seda e sabiá na alimentação de cabras leiteiras. *Revista Caatinga, 24*(2), 158-164.

Siqueira, M. C. B., Ferreira, M. A., Monnerat, J. P. I. S., Silva, J. L., Costa, C. T. F., Conceição, M. G., ... Melo, T. T. B. (2017). Optimizing the use of spineless cactus in the diets of cattle: total and partial digestibility, fiber dynamics and ruminal parameters. *Animal Feed Science and Technology, 226*(1), 56-64. DOI: https://doi.org/10.1016/j.anifeedsci.2016.12.006

Sniffen, C. J., O'Connor, J. D., & Van Soest, P. J. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(12), 3562-3577. DOI: https://doi.org/10.2527/1992.70113562x

Souza, C. M. S., Medeiros, A. N., Costa, R. G., Pereira, E. S., Azevedo, P. S., Lima Junior, V., ... Souza, A. P. (2015). Características da carcaça e componentes não integrantes da carcaça de caprinos Canindé suplementados na caatinga. *Revista Brasileira de Saúde e Produção Animal, 16*(3), 723-735. DOI: https://doi.org/10.1590/S1519-99402015000300022

Van Soest, P. J., Robertson, J. B., & Lewis, B.A. (1991). Methods for dietary fiber, neutral detergent fiber, and non-starch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74*(10), 3583-3597. DOI: 10.3168/jds. S0022-0302(91)78551-2

Weiss, W. P., Conrad, H. R., & Pierre, N.R ST. (1999). A theoreticallybased model for predicting total digestible nutrient values of forages and concentrates. *Animal Feed Science and Technology, 39*(1-2), 95-110. DOI: https://doi.org/10.1016/0377-8401(92)90034-4

Wheeler, T. T., Cundiff, L. V., Koch, R. M. (1993). Effects of marbling degree on palatability and caloric content of beef. *Beef Research Program Progress Report, 4*(Part 1), 133-134.

Xazela, N. M., Chimonyo, M., Muchenje, V., & Marume, U. (2012). Effect of sunflower cake supplementation on meat quality of indigenous goat genotypes of South Africa. *Meat Science, 90*(1), 204-208. DOI: https://doi.org/10.1016/j.meatsci.2011.07.001