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RESEARCH ARTICLE

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Influence of genotypes of spineless cacti on feedlot lamb carcass characteristics and meat quality

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Abstract

Aim of study: The objective of this study was to evaluate the effects of spineless cactus genotypes (*Nopalea cochenillifera* or *Opuntia stricta*) on the carcass characteristics and meat quality of feedlot lambs.

Area of study: Federal Rural University of Pernambuco, Recife, Brazil.

Material and methods: Thirty-six uncastrated male Santa Inês lambs (22.0±2.91 kg of body weight) were used in a completely randomized design, with three dietary treatments: (1) Tifton hay as exclusive roughage; (2) *Nopalea* spineless cactus; or (3) *Opuntia* spineless cactus as a partial replacement for Tifton hay; the animals were slaughtered after 86 days of feedlot.

Main results: The *Nopalea* and *Opuntia* diets increased ($p<0.05$) the empty body weight and the weight of the cold carcass. The cold carcass yield for lambs fed diets with spineless cactus was higher ($p<0.05$). The spineless cactus diets led to a greater amount ($p<0.05$) of internal fat and carcass fat. Spineless cactus increased the weight, yield, and fattening score of the carcasses of lambs. The meat from animals fed with spineless cactus showed higher ether extract content ($p<0.05$). The score attributed to meat color in the *Opuntia* treatment was higher ($p<0.05$), as well as the characteristic flavor for the *Nopalea* treatment.

Research highlights: Spineless cactus, regardless of the genotype, increases the weight, yield, and fattening of the carcass of feedlot lambs.

Additional key words: cactus cladodes; consumer preference; physicochemical parameters; small ruminants; tissue composition.

Abbreviations used: BW (body weight); BY (biological yield); CCW (cold carcass weight); CL (cooking losses); DM (dry matter); EBW (empty body weight); FL (femoral length); HCW (hot carcass weight); LC (loss by cooling); LMA (*Longissimus muscle* area); ME (metabolizable energy); OEM (Orelha de Elefante Mexicana); SF (shear force); SFT (subcutaneous fat thickness); WHC (water-holding capacity).

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Introduction

For small ruminants raised in dry and semi-arid conditions, the spineless cacti are an attractive and strategic source of feed. These *Cactaceae* have high levels of non-fibrous carbohydrates (523 g/kg of dry matter (DM)), low content of neutral detergent fiber (94.7 g/kg DM), and high coefficient of DM digestibility (Costa et al., 2012; Siqueira et al., 2017). However, the dissemination of carmine cochineal (*Dactylopius opuntiae*), a debilitating pest of forage cactus cultivation, is a limiting factor to the production of this fodder in areas of Africa, America, and Asia. In this context, two genotypes resistant to carmine cochineal have been developed: 'Miúda' (*Nopallea cochenillifera* Salm Dyck) and Orelha de Elefante Mexicana – 'OEM' (*Opuntia stricta* Haw.) (Vasconcelos et al., 2009).

Diets containing spineless cacti change the profile of rumen fermentation in sheep, compared to diets that use only grasses as roughage, which, consequently, can affect the performance and characteristics of the carcass and meat. Araújo et al. (2020), when evaluating the effects of the inclusion of the cactus 'OEM' in sheep diets, observed that the inclusion of cactus increased the acetate, propionate, butyrate, and total short-chain fatty acid concentrations in the rumen.

Previous studies have shown that the addition of 'Miúda' spineless cacti in lamb diets for lambs enhances growth performance and carcass characteristics without degrading the quality of the meat (Cardoso et al., 2021). Furthermore, it enhances consumer acceptance and raises the carcass finishing fat (Moura et al., 2020). Nevertheless, no research has assessed 'OEM' spineless cactus's impact on lamb finishing.

Despite the variation already reported in the literature between the chemical composition of the different spineless cactus genotypes, such as the content of non-fibrous carbohydrates and crude protein (Siqueira et al., 2019; Usman et al., 2022), some evidence suggests that 'OEM' genotype has the potential to replace 'Miúda' in the diet of dairy cattle (Monteiro et al., 2018; Silva et al., 2018) and beef lambs (Lopes et al., 2020; Silva et al., 2021).

It was therefore hypothesized that lambs fed 'OEM' spineless cactus would have meat and carcass characteristics comparable to those fed 'Miúda' spineless cactus, and that they would be a better option than lambs fed grass hay. Therefore, the objective of this study was to evaluate the effects of the two spineless cactus genotypes ('OEM' – *Opuntia* or 'Miúda' – *Nopalea*) on the carcass characteristics and meat quality of feedlot lambs.

Material and methods

The animals were handled and cared according to the guidelines and recommendations of the Committee of Ethics in the Use of Animals of the Federal Rural University of Pernambuco (UFRPE), under license number (142/2018). The experiment was performed in the Department of Animal Science, UFRPE, in Recife, Brazil (8º04'03''S and 34º55'00''W).

The present study, which is part of a broader project, was developed based on a prior methodology by Lopes et al. (2020). To determine nutrient intake and obtain carcasses, 36 uncastrated male Santa Inês lambs, with an average age of 6±1 months and an average initial body weight (BW) of 22.0±2.9 kg, were used. The lambs were distributed into three treatments and 12 replications, in a completely randomized design. The experimental period lasted 86 days, with the first 30 days for the adaptation of the animals to the facilities, the diets, and the management, and the remaining 56 days for evaluation and data collection. The experimental area was composed of individual stalls, with dimensions of 1.0 × 1.8 m, including drinkers and feeders, arranged in a covered shed. Prior to the experiment's commencement, all the animals were identified, treated for the control of endoparasites, and vaccinated against clostridia.

The diets were formulated to be isonitrogenous and to meet the nutritional requirements of lambs weighing 25 kg, with an average daily gain of approximately 200 g, according to the nutritional recommendations of the National Research Council (2007). The chemical composition of ingredients is presented in Lopes et al. (2020).

Experimental diets consisted of three treatments: (1) Tifton hay as exclusive roughage; (2) 'Miúda' spineless cactus (*Nopalea cochenillifera* Salm Dyck); or (3) 'OEM' spineless cactus (*Opuntia stricta* Haw.) (3) as a partial replacement for Tifton hay (75%) (Lopes et al., 2020), with roughage:concentrate ratio of 60:40 (dry matter basis).

The spineless cactus was crushed daily, in a machine suitable for forage cactus processing. To lessen animal selection, the hay was ground in a forage machine equipped with an 8 mm sieve screen, and mixed with the other ingredients. Diets were offered as a total mixed ration twice a day (08:00 h and 15:00 h), with 15% of the leftovers being allowed. The water was provided *ad libitum*. Informations regarding collection, processing and chemical analysis of feed and leftovers were reported by Lopes et al. (2020), in research associated with the present study. The intakes of DM and metabolizable energy (ME) were calculated.

After 86 days of feedlot, the animals (average final age of 9 months and average final weight of 36.1 kg) were 16 hours fasted, and they were weighed right before slaughter in order to determine their BW. Then, the animals were stunned with a penetrating captive bolt pistol (Ctrade®, Tec 10 PP) driven by an exploding cartridge, and suspended by their hind limbs using hooks, followed by bleeding of the carotid artery and sectioning of the jugular vein. All blood was collected and weighed in a properly identified pail and, after bleeding, manual skinning and evisceration were performed.

Following skinning and evisceration, the head (sectioned at the atlantooccipital joint), legs (sectioned at the carpal and tarsus-metatarsal joints), and tail were separated. All organs, as well as the internal fat of the gastrointestinal tract, were separated and weighed individually. Then, the carcass was weighed for the determination of hot carcass weight (HCW).

Afterwards, the gallbladder, bladder, and gastrointestinal tract (rumen, reticulum, omasum, abomasum, small and large intestines) were weighed when full, then emptied, washed, and weighed again. The empty body weight (EBW) was calculated as the difference between the sum of the gastrointestinal tract, gallbladder and bladder weights, head, carcass, skin, tail, legs, and blood and the sum of the contents of the gastrointestinal tract, bladder, and gallbladder (Cezar & Souza, 2007).

The hot carcasses were taken to a cold chamber with an average temperature of 4°C, where they remained for 24 hours, suspended by the tendon of the gastrocnemius muscle using hooks. After this cooling period, the carcasses were weighed to obtain the cold carcass weight (CCW).

To evaluate the pH of the carcass, it was measured at 0 h and 24 h postmortem, from the *Longissimus dorsi* muscle, with the aid of a pH meter, according to the methodology described by Rodrigues et al. (2008). On the other hand, chilling losses (CL) was quantified by the following formulas: CL (kg) = HCW – CCW, and CL (%) = (HCW – CCW/HCW) × 100. The biological yield (BY), hot carcass yield (HCY), and cold carcass yield (CCY) were determined by the following formulas: BY = HCW/EBW × 100; HCY = HCW/BW at slaughter × 100; and CCY = CCW/BW at slaughter × 100, respectively.

Later, the carcasses were divided sagittally, and the half carcasses were sectioned into six anatomical regions constituting the meat cuts; this led to the following cuts: neck, shoulder, ribs, saw, loin and leg. Also, the relative regional composition of the carcass was determined by the relative calculation of each cut by the reconstituted weight of the left half carcass, according to Cezar & Sousa (2007).

To obtain the *Longissimus muscle* area (LMA) in the carcass, a cut was performed between the 12th and 13th rib for the exposure of the *Longissimus dorsi* muscle, whose area was hatched with a permanent marker on clear plastic film, which was subsequently measured with a digital planimeter (HAFF®, Digiplan model) using the mean of three readings. Subcutaneous fat thickness (SFT) was measured with a caliper on the *Longissimus dorsi* muscle (Cezar & Sousa, 2007).

The left leg of each animal was frozen (-15°C) and vacuum-packed for the analysis of tissue composition. To determine the tissue composition, the legs were thawed for 24 hours under refrigeration (4°C). The tissue composition was determined (Purchas et al., 1991) and obtained through dissection in accordance with Cesar & Souza (2007); the leg muscularity index was calculated as $\sqrt{(P5M/FL)}$ / FL, where P5M represents the weight of the five muscles (*femoral biceps, femoral quadriceps, semimembranosus, semitendinosus*, and *adductor*), in g; and FL is the femoral length, in cm.

The loins (*Longissimus lumborum*) were employed for the physicochemical study of the meat after being refrigerated (4°C) for 24 hours. The evaluations of meat color: lightness (L*), redness (a*), and yellowness (b*) (MINOLTA CORP., 1994) were performed with the aid of a Minolta Chroma Meter CR-400 digital colorimeter, after exposure to oxygen for 50 min. The pH of the meat was measured with a potentiometer (Testo Instrument Co. LTD., Germany), according to Rodrigues et al. (2008). The water-holding capacity was performed according to the methodology of Santos-Silva et al. (2002). Samples of approximately 300 mg were weighed on filter papers, and pressed for five minutes, using a weight of 3.4 kg. Following this procedure, the samples were discarded and the filter sheets were weighed.

Assessments of cooking losses (CL) and shear force were performed according to Wheeler et al. (1993). To determine the CL, the loin was first weighed, and then roasted in a preheated oven at 200ºC until it reached 75ºC in the geometric center. The loin was then weighed again, and the difference between the two weights was the CL. The shear force (SF) test was then run using the leftover cooking samples. Using 2.5-cm-thick steaks four cylinders (1.27-cm diameter) were removed from each sample, longitudinal to the direction of the muscle fibers, and sheared perpendicularly to the orientation of the fibers. The required cutting force was measured using Warner-Bratzler Shear Force equipment, with a load cell of 25 kgf and a speed of 20 cm/min. Regarding the chemical composition of the fresh meat (*Semimembranosus* muscle), the analyses of moisture, crude protein, ether extract, and ash were determined according to AOAC (1990).

Sensory analysis of meat (*Longissimus lumborum*) was performed using quantitative descriptive analysis, on an unstructured hedonic scale, as described by Ston & Sidel (2004). In individual booths, 13 trained judges evaluated the attributes: overall evaluation, color, characteristic aroma, tenderness, juiciness and characteristic flavor. For the preparation of the meat samples, they were cooked in a preheated oven at 200ºC, up to 75ºC of the temperature of the geometric center, and later fractioned into cubes of 2.5 cm and 15 g of weight. The evaluation followed the experimental model of complete blocks so that each sample (one for animal) was evaluated in triplicate by each judge.

The experimental design was completely randomized, with the initial BW of the animals as a covariate. The analyzed variables were interpreted using an analysis of variance, at a significance level of 5%, using the Statistical Analysis System (SAS, 2009), according to the following model:

$$Y_{ij} = \mu + T_i + \beta (X_{ij} – X) + e_{ij};$$

where Y_{ij} is the observed dependent variable; μ is the overall mean; T_i is the treatment effect (i = 1 to 3); $\beta (X_{ij} – X)$ is the covariate effect; and e_{ij} is the experimental error. The means were compared by Tukey's test ($p<0.05$).

Results

The DM and ME intakes presented differences according to the diets ($p<0.05$), being highest for *Nopalea* (Table 1). There was no effect of treatments ($p>0.05$) on slaughter BW, with a mean value of 34.4 kg. However, the content of the gastrointestinal tract, expressed in kg and as percentage of

Table 1. Body weight (BW), intake and carcass characteristics of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Item[1]	Diets			SEM[3]	p-value
	Tifton hay	*Nopalea*	*Opuntia*		
BW (kg)					
Initial[2]	22.4	22.6	22.8	-	-
At slaughter (kg)	33.7±2.84	35.0±4.55	34.6±3.79	0.641	0.621
Daily intake (g/d)					
Dry matter[2]	1129±149b	1290±175a	1172±176ab	0.030	0.010
Metabolizable energy	2.63±68b	3.31±130a	2.67±103b	0.028	0.009
Carcass characteristics					
EBW (kg)	26.9±2.75b	30.4±4.08a	30.1±3.14a	0.620	0.009
GITC (kg)	6.79±1.38a	4.68±0.79b	4.54±0.85b	0.244	0.001
GITC:BW at slaughter (%)	20.1±3.87a	13.3±1.77b	13.1±1.64b	0.689	0.001
HCW (kg)	15.3±1.77b	17.3±2.42a	17.1±1.97a	0.376	0.020
CCW (kg)	14.6±1.70b	16.6±2.37a	16.4±1.86a	0.366	0.019
CL (kg)	0.70±0.11	0.67±0.08	0.68±0.13	0.019	0.742
CL (%)	4.60±0.52a	3.90±0.56b	3.97±0.39b	0.098	0.003
HCY (%)	45.4±2.88b	49.4±2.28a	49.4±1.82a	0.503	0.001
CCY (%)	42.8±2.82b	47.1±2.21a	47.5±1.78a	0.503	0.001
BY (%)	56.9±1.20	57.1±2.24	56.9±1.63	0.291	0.948
LMA (cm²)	9.98±1.72b	12.6±3.26a	11.0±1.94ab	0.435	0.047
SFT (mm)	0.63±0.15	0.61±0.19	0.57±0.16	0.028	0.870
pH 0h	6.97±0.10	6.93±0.18	6.91±0.18	0.026	0.648
pH 24h	5.43±0.10	5.43±0.08	5.49±0.10	0.016	0.295

[1] EBW: empty body weight. GTIC: gastrointestinal tract content. HCW: hot carcass weight. CCW: cold carcass weight. CL: cooling losses. HCY: hot carcass yield. CCY: cold carcass yield. BY: biological yield. LMA: *Longissimus* muscle area. SFT: subcutaneous fat thickness. [2] Values obtained by Lopes et al. (2020). [3] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

slaughter weight (%), was higher in animals fed the Tifton diet than in their counterparts (p<0.05).

The use of spineless cactus (*Nopalea* and *Opuntia*) increased the EBW, HCW, CCW, HCY and CCY yields (p<0.05). The CL, expressed in kg, did not present differences (p>0.05), with an average of 0.68 kg; however, expressed as proportion of carcass weight, was highest for lambs from the Tifton hay treatment (p<0.05).

The *Nopalea* diet led to an increase in the LMA, compared to the Tifton diet (p<0.05). In contrast to the other treatments, the carcass of lambs fed *Opuntia* did not exhibit any differences in the LMA (p>0.05). Additionally, SFT did not differ between treatments (p>0.05).

In relation to the commercial meat cuts (Table 2), there was no effect of the diets on the absolute weights of the shoulder, neck, saw, and leg cuts (p>0.05). The ribs and loin were heavier for lambs from the *Nopalea* treatment, compared to Tifton hay (p<0.05); however, lambs from the *Opuntia* treatment did not differ from the others (p>0.05). The yields of cuts were not influenced (p>0.05) by treatments and, they were, on average: shoulder: 19.6%; ribs: 19.5%; saw: 8.1%; loin: 9.0%; and leg: 34.8%.

The spineless cactus treatments (*Nopalea* and *Opuntia*) led to a higher fat deposition (kg and %; p<0.05) and lower muscle/fat ratio (p<0.05). The weight and proportion of the other tissues in the leg did not vary (p>0.05) (Table 3).

The use of spineless cactus increased the weight of the lambs' livers (p<0.05; Table 4). When evaluated as a percentage of BW, liver weight was 2.24% for the lambs that received the *Nopalea* treatment, 2.16% for *Opuntia*, and 1.87% for Tifton hay. The weights of the rumen and reticulum of *Opuntia*-fed lambs and weight of the internal fat of lambs fed *Nopalea* were higher than those fed Tifton hay (p<0.05).

There was no difference in the physicochemical parameters of the meat (*Longissimus lumborum*) (p>0.05; Table

Table 2. Weight of commercial cuts of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Weight (kg)	Diets			SEM[1]	p-value
	Tifton hay	*Nopalea*	*Opuntia*		
Shoulder	1.38±0.12	1.56±0.21	1.50±0.28	0.039	0.145
Neck	0.61±0.23	0.70±0.14	0.70±0.11	0.029	0.329
Ribs	1.35±0.20b	1.61±0.24a	1.48±0.21ab	0.040	0.007
Saw	0.57±0.10	0.63±0.11	0.65±0.10	0.018	0.156
Loin	0.61±0.09b	0.73±0.17a	0.70±0.08ab	0.022	0.042
Leg	2.50±0.31	2.72±0.41	2.70±0.37	0.063	0.265

[1] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

Table 3. Tissue composition of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Item	Diets			SEM[1]	p-value
	Tifton hay	*Nopalea*	*Opuntia*		
Muscle (kg)	1.62±0.20	1.74±0.29	1.72±0.25	0.042	0.476
Muscle (%)	65.8±2.17	66.8±2.84	66.3±1.89	0.392	0.775
Bone (kg)	0.51±0.05	0.53±0.08	0.51±0.09	0.013	0.834
Bone (%)	20.7±1.42	20.2±1.35	19.7±1.80	0.274	0.489
Total fat (kg)	0.16±0.05b	0.22±0.05a	0.22±0.06a	0.012	0.001
Subcutaneous fat (SF; kg)	0.12±0.04b	0.16±0.04a	0.15±0.05ab	0.008	0.031
Intermuscular fat (IF, kg)	0.04±0.01b	0.06±0.02a	0.06±0.02a	0.004	0.002
Total fat (%)	6.65±1.74b	8.73±1.40a	8.76±1.83a	0.319	0.004
Other tissues (kg)	0.19±0.03	0.11±0.04	0.13±0.03	0.006	0.335
Other tissues (%)	6.70±0.91	4.21±1.56	5.07±1.17	0.216	0.274
Muscle:Bone ratio	1.88±0.29	1.89±0.21	1.97±0.20	0.040	0.668
Muscle:Fat ratio	5.35±1.42a	3.74±0.64b	3.95±0.88b	0.209	0.001
SF:IF ratio	3.19±0.97	3.04±1.45	2.39±0.60	0.187	0.195
Leg muscle index	0.40±0.03	0.42±0.03	0.41±0.05	0.006	0.706

[1] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

5). Concerning the chemical composition, the groups differed only for EE and moisture, with higher values of EE for meat from animals fed with spineless cactus ($p<0.05$). The meat from lambs fed Tifton hay diet showed higher moisture compared to *Nopalea* diet ($p<0.05$).

In the sensory evaluation of meat (*Longissimus lumborum*), there was no difference between treatments for the parameters: general appearance, characteristic sheep aroma, tenderness, and juiciness ($p>0.05$; Table 6). However, the score attributed to meat color in the *Opuntia* treatment was higher, as well as the characteristic flavor of sheep meat for the *Nopalea* treatment, when compared to Tifton hay ($p<0.05$).

Discussion

In general, the use of spineless cactus (*Nopalea* and *Opuntia*) increased the EBW, HCW, and CCW of growing lambs. According to Batista et al. (2009) and Siqueira et al. (2017), this cactus's high degradability, low content of fibrous carbohydrates, and high content of non-fibrous carbohydrates, along with its high levels of total digestible nutrients, maximize the capacity for ruminal fermentation; thus, it is probable that there was an increase of nutrient flow in the tissues of the animals fed spineless cactus, favoring muscular anabolism (Ribeiro et al., 2017).

Table 4. Organs, viscera, and inedible offals of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Item[1]	**Diets**			**SEM**[2]	**p-value**
	Tifton hay	***Nopalea***	***Opuntia***		
Organs (kg)					
Heart	0.14±0.19	0.16±0.24	0.15±0.25	0.004	0.064
Liver	0.50±0.60b	0.68±0.12a	0.65±0.12a	0.022	0.001
Kidneys	0.98±0.18	0.11±0.14	0.11±0.27	0.004	0.228
Spleen	0.60±0.10	0.73±0.14	0.70±0.17	0.003	0.093
Pancreas	0.57±0.13	0.58±0.18	0.80±0.12	0.002	0.402
Lungs	0.34±0.38	0.37±0.50	0.38±0.89	0.011	0.386
Organs:EBW (%)	4.50±0.37	4.79±0.26	4.76±0.47	0.067	0.148
Viscera (kg)					
Rumen	0.67±0.73b	0.77±0.12ab	0.85±0.10a	0.021	0.002
Reticulum	0.11±0.24b	0.13±0.25ab	0.15±0.28a	0.005	0.039
Omasum	0.99±0.25	0.11±0.22	0.12±0.27	0.008	0.111
Abomasum	0.14±0.31	0.14±0.34	0.15±0.24	0.021	0.399
Small intestine	0.64±0.85	0.70±0.82	0.71±0.78	0.014	0.135
Large intestine	0.33±0.30	0.34±0.59	0.36±0.60	0.009	0.306
Viscera:EBW (%)	7.77±0.71ab	7.54±0.59b	8.07±0.43a	0.104	0.045
Inedible offals (kg)					
Skin	2.34±0.21b	2.83±0.44a	2.57±0.22ab	0.062	0.009
Blood	1.27±0.22	1.30±0.22	1.22±0.24	0.038	0.634
Head	1.97±0.17	1.99±0.22	1.96±0.19	0.033	0.952
Offals:EBW (%)	23.9±1.14a	23.1±0.81a	22.0±0.70b	0.199	0.001
Total internal fat	0.91±0.34b	1.46±0.47a	1.28±0.38ab	0.077	0.004
Internal fat:EBW (%)	3.33±0.95b	4.73±1.24a	4.25±1.07ab	0.208	0.013

[1] EBW: empty body weight. [2] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

The highest gastrointestinal tract weight in grass hay-fed animals can be attributed to the lower effective rumen degradability of hay DM (365.7 g/kg DM; Jobim et al., 2011), compared to spineless cactus (711 g/kg DM; Batista et al., 2009). Still, in this context, the greater weight of the gastrointestinal tract in the lambs that received grass hay reflected negatively on the carcass yields.

It is worth emphasizing that the native breeds that were selected for tropical or semi-arid tropical regions, where food availability is seasonal, require the deposition and rapid mobilization of body reserves (especially of internal fatty tissues), as an important factor for survival under these conditions (Mirkena et al., 2010; Regadas Filho et al., 2013). For this reason, it has been reported (Ribeiro et al., 2017; Oliveira et al., 2018; Cardoso et al., 2021) that the Santa Inês breed accumulates substantial amounts of internal fat despite having low subcutaneous fat deposition. These reports are consistent with the findings of this work. Although they had high internal fat deposition, lambs fed *Opuntia* did not differ from the Tifton hay treatment. This allows us to infer that they had smaller losses with slaughter by-products (by-products: EBW) and greater energy use efficiency of the *Opuntia* diet compared to the *Nopalea* diet.

The liver plays a central role in the metabolism of organic acids and dietary proteins. It may have hypertrophied to process the higher flow of these compounds in the body of the animals fed spineless cactus (Hentz et al., 2016; Ribeiro et al., 2017; Cardoso et al., 2021).

According to Costa et al. (2017), the use of spineless cactus 'Miúda' enriched with 1.5% urea, potentiated the maximum concentration of acetate in the rumen, estimated to be 70.9 mmol/mL. Thus, it is possible that, in the present study, the same food, which promoted higher DM and TDN intakes, resulted in the higher fermentation of non-fibrous carbohydrates and energy availability in short-chain fatty acids; this was mainly in the form of acetate, the fundamental

Table 5. Physicochemical characteristics of meat of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Item	Diets			SEM[2]	p-value
	Tifton	*Nopalea*	*Opuntia*		
Lightness (L*)	38.7±1.87	39.6±1.61	39.7±2.51	0.355	0.508
Redness (a*)	16.0±1.43	16.9±1.69	16.7±1.96	0.294	0.427
Yellowness (b*)	8.78±1.16	9.77±1.12	9.58±1.31	0.213	0.159
pH	5.43±0.10	5.43±0.08	5.49±0.10	0.016	0.295
WHC (%) [1]	25.9±2.70	25.4±3.20	25.5±3.18	0.507	0.922
Cooking loss (%)	43.4±2.59	43.7±2.49	42.4±2.80	0.454	0.499
Shear force (kg/cm²)	2.18±0.27	2.18±0.51	2.30±0.64	0.084	0.257
Ash (%)	1.24±0.35	1.33±0.26	1.38±0.38	0.057	0.653
Crude protein (%)	18.5±0.47	18.9±0.80	19.1±1.06	0.144	0.217
Ether extract (%)	1.71±0.47b	2.31±0.50a	2.28±0.54a	0.093	0.020
Moisture (%)	78.2±0.67a	76.9±1.06b	77.4±1.43ab	0.207	0.020

[1] WHC: water-holding capacity (%). [2] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

Table 6. Sensory analysis of meat of lambs fed with spineless cactus genotypes resistant to carmine cochineal

Item	Diets			SEM[1]	p-value
	Tifton	*Nopalea*	Opuntia		
Overall evaluation	7.09±1.12	7.28±0.99	7.21±1.03	0.091	0.226
Color	5.21±1.56b	5.30±1.69ab	5.54±1.38a	0.142	0.037
Characteristic aroma	3.19±1.73	3.33±1.81	3.36±1.79	0.163	0.317
Tenderness	6.58±1.76	6.75±1.80	6.54±1.78	0.164	0.563
Juiciness	4.67±2.24	4.90±2.27	4.64±2.36	0.211	0.251
Characteristic flavor	3.30±1.83b	3.81±2.04a	3.46±1.92ab	0.182	0.009

[1] SEM: standard error of the mean. The averages in the lines followed by different letters are statistically different by the Tukey test at 5% probability.

short-chain fatty acid used in the energetic supply of the visceral tissues and the main substrate for lipogenesis in adipose tissue (Campbell et al., 2016), resulting in a higher visceral energy reserve.

The development of the rumen and reticulum can be influenced by the proportion of neutral detergent fiber in the diet, causing the filling and retention of food in these compartments, favoring muscle development. However, this behavior was observed inversely in the present study. It is worth mentioning that the *Opuntia* diet showed higher humidity and, as a result, higher fresh matter intake (6159 g/day). This could have led to distension and encouraged the increased formation of these compartments. In contrast, they were 1005 and 5494 g/day in the Nopalea and control diets, respectively. Silva et al. (2020) reported that the weight of the stomach was greater in lambs fed with spineless cactus, regardless of genotype. In addition, they suggested that greater papillary development may induce an increase in the mass of the fore-stomach, especially the rumen.

The difference in the chemical composition of the meat between the treatments can be related to the increase in EBW and the greater deposition of fat in animals fed with spineless cactus. Because of its energy content, spineless cactus in the diet of lambs increases fattening of carcass and the EE of meat (Moura et al., 2020). According to Abdullah & Qudsieh (2008), the decrease in meat moisture content is related to increased fat deposition, which is a late-maturing tissue that takes the place of muscle moisture and leads to a decrease in the amount of water in the muscles. The higher degree of intermuscular and subcutaneous adiposity of the *Nopalea* treatment may have intensified the perception of the characteristic flavor attribute in the sensory evaluation of sheep meat.

In conclusion, both genotypes of spineless cacti increase the weight, yield, and fattening of feedlot lamb carcasses. For lambs raised in carmine cochineal-infested locations, the genotype 'Orelha de Elefante Mexicana' offers a healthier option.

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