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ANIMAL PRODUCTION

Replacement of corn silage with spineless cactus in sheep diet: carcass and meat sensory characteristics

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ABSTRACT. This study evaluated the effect of replacing corn silage with spineless cactus, in combination with Tifton 85 hay or sugarcane bagasse, on the carcass measurements and sensory properties of the meat of lambs finished in feedlot. Twenty-one, intact, Santa Inês males, with an initial body weight of 22.86 ± 2.87 kg and an average age of 150 days, were individually confined for 74 days and fed at will three treatments diets: Corn silage (CS); Spineless cactus + Tifton 85 hay (CT) and Spineless cactus + sugarcane bagasse (CB). Lambs fed CT had a wider croup ($p < 0.05$) compared to animals fed CS. The replacement of corn silage with CT or CB did not influence ($p > 0.05$) the body length, withers height or chest circumference of the lambs. Values of carcass length and compactness index were similar ($p > 0.05$) between treatments. There was a high and positive correlation ($p < 0.05$) between chest width (0.82) and chest circumference (0.81) of animals with cold carcass weight. The odor and taste of sheep meat fed CT or CB was more accepted when compared to the meat of animals fed corn silage. The replacement of corn silage with spineless cactus in combination with Tifton 85 hay or sugarcane bagasse improves the sensory quality of sheep meat, but does not interfere with carcass measurements.

Keywords: biometrics; sugarcane bagasse; Tifton 85 hay; *Nopalea cochenillifera*; acceptance test.

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Introduction

In northeastern Brazil, sheep farming stands out as one of the most important livestock activities, however due to prolonged droughts and a short rainy season there is a deficit in the supply of native forage for herds, resulting in poor animal performance (Pereira Filho et al., 2013). Therefore, the supply of supplementary feed in the trough represents an alternative to minimize the negative impact of forage deficit on the performance of sheep (Wanapat, 2009).

Corn silage has a high nutritional value for sheep (Moreno et al., 2010a), but the cultivation of corn for making silage is hampered by drought in northeastern Brazil, which encumbers the use of silage as a food resource for herds in this region. In this context, the use of xerophyte forages, such as spineless cactus (*Nopalea cochenillifera* Salm-Dick), is sustainable alternative for sheep meat production systems developed in semiarid areas (Awawdeh, 2011).

Spineless cactus is a cactus widely grown in northeastern Brazil and has a high content of non-fiber carbohydrates (433 g kg^{-1}) and high ruminal degradability (700 g kg^{-1}) (Batista et al., 2009). However, some studies show the need to combine spineless cactus with effective fiber forage, to avoid ruminal disorders and optimize animal performance (Maciel et al., 2019; Pinho et al., 2018; Vieira et al., 2008). Among the forages with the potential to be combined with spineless cactus in sheep diet, Tifton 85 hay (Cardoso et al., 2019) and sugarcane bagasse (Ribeiro et al., 2017) stand out.

In an extensive literature review, Lima Júnior et al. (2016) found evidence that indicates that the type of forage can interfere with the sheep carcass and meat characteristics. Therefore, the objective was to evaluate the effect of replacing corn silage with spineless cactus combined with Tifton 85 hay or sugarcane bagasse on the carcass characteristics and acceptance of confined sheep meat.

Material and methods

All procedures performed with the animals were approved by the Ethics Committee on the Use of Animals (CEUA) of the Federal University of Alagoas under number 029/2015.

The experiment was conducted at the Demonstration and Experimental Center of the Animal Science Program (*CEDEZOO*), Federal University of Alagoas - *Campus Arapiraca*. It is located at geographical coordinates: 9°45'6''S, 36°39'37''W and 280 m altitude. The climate is As, classified according to Koppen, characterized by tropical with dry season.

The experiment was conducted with twenty-one male, non-castrated Santa Inês sheep, with an initial body weight (BW) of 22.86 ± 2.87 kg and an average age of 150 days, confined in individual pens with 1.12 m^2, provided with feeders and drinkers, previously identified, dewormed and distributed in a completely randomized design in three treatment diets (corn silage, Tifton hay and sugarcane bagasse), with 07 repetitions each.

The animals were fed at will, receiving diets that allowed gains of 200 g day^{-1} (National Research Council [NRC], 2007) (Table 1).

Table 1. Percent and chemical composition of experimental diets (% DM).

Variables	Corn silage	Spineless cactus +hay	Spineless cactus +bagasse
Percent composition (%)			
Corn Silage	65.00	0	0
Tifton 85 hay	0	30.00	0
Sugarcane bagasse	0	0	30.00
Spineless cactus	0	35.00	35.00
Corn grain	13.00	13.00	8.00
Soybean meal	19.00	19.00	24.00
Mineral mix	3.00	3.00	3.00
Chemical composition (%)			
Dry matter	28.68	43.35	50.26
Organic matter	90.97	90.09	90.94
Crude protein	14.98	14.79	14.77
Ether extract	2.34	2.08	1.66
NDF[a]	57.42	42.84	43.65
Hemicellulose	28.13	18.72	13.46
ADF[b]	29.99	24.12	30.19
NFC [c]	16.23	30.38	30.86

[a]Neutral detergent insoluble fiber; [b] Acid detergent insoluble fiber; [c]Non-fiber carbohydrates.

The fresh spineless cactus was ground in a forage chopper (Trapp, model JK 700) immediately before supply. Tifton 85 hay was coarsely ground (4 cm sieve) in a shredder (Trapp, model TRF-90F). Corn grain and soybean meal were ground in a shredder through a 2 mm sieve. Diets were offered as a complete mixture in two daily meals (08:00 a.m. and 04:00 p.m.).

The experimental period lasted 74 days, with 14 days for adaptation and 60 days for data collection. Animals were weighed fortnightly to monitor weight gain. On the seventieth day, biometric measurements were taken using a measuring tape and an *ovinometer*.

The measures taken were: body length (distance between the anterior end of the shoulder and the rear tip of the buttocks), withers height (distance between a straight line from the withers to the ground), rump height (distance between a straight line from the croup to the ground), chest width (distance between the lateral sides of the scapular-humeral joints), chest (distance between the withers at its median portion to the sternum), chest circumference (contour of the thoracic circumference measured behind the shoulder), croup width (distance between the greater trochanter of the femur) and thigh circumference (measured in the middle part of the leg, above the femoralo-tibial patellar joint). The body condition was estimated by palpating the dorsal region of the spine, checking the amount of fat and muscle found in the angle formed by the dorsal and transverse processes, assigning scores from 1 to 5, where score 1 = very thin, score 2 = thin, score 3 = moderate, score 4 = fat and score 5 = very fat. All measurements were taken with the animals on a horizontal and flat surface and always by the same person, in order to minimize errors arising from the evaluator (Cezar & Sousa, 2007).

After the confinement period, lambs were fasted for solid diet for 24 h. Before slaughtering, animals were weighed to obtain body weight at slaughter (BWS), stunned by cerebral and later slaughtered by cutting the jugular veins and carotid arteries. Skinning and evisceration were performed, removing the head (section at the atlanto-occipital joint) and the limbs (section at the carpal- and tarsal-metatarsal joints). The hot carcass was taken to a cold chamber at 4°C for 24h, after which the cold carcass was then weighed, measured and cut into meat cuts (Cezar & Sousa, 2007).

Cold carcass morphometric measurements were taken using an *ovinometer* (for linear measurements) and a tape measure (for circumference measurements). The following measures were taken on the cold carcass: external carcass length (distance between the cervical-thoracic joint and the first intercoccygeal joint), internal carcass length: (maximum distance between the anterior edge of the pubic bone and the anterior edge of the first rib at its midpoint), leg length (distance between the greater trochanter of the femur and the lateral edge of the tarsal-metatarsal joint), croup width (maximum width between the trochanters of the femurs), chest width (width of the chest at the widest rib width), chest depth (maximum distance between the sternum and withers), croup perimeter (perimeter at the croup region, based on the trochanters of the femurs), leg circumference (measured in the middle of the leg, above the femoral-tibial patellar joint), chest circumference (contour of the thoracic circumference measured behind the shoulder). Carcasses were also classified according to the conformation scores into 1 (poor), 2 (fair), 3 (good), 4 (very good) or 5 (excellent) and according to finishing into 1 (very lean), 2 (lean), 3 (intermediate), 4 (fat) or 5 (very fat) (Cezar & Sousa, 2007).

The loin meat cut was placed in a resistant plastic bag and frozen for further analysis. After 180 days of freezing, the muscle was divided into sub-samples of approximately 2 cm^3 and roasted without spices and salt, on a preheated grill until its internal temperature reached 75°C.

The sensory analysis was approved by the Human Research Ethics Committee, following Resolution 196/96 of the National Health Council of Brazil. The acceptance test of roasted meat (*Longissimus lumborum*) was carried out with the participation of a panel of 51 untrained tasters, likely consumers of sheep meat, represented by 57% women and 43% men aged between 20 and 40 years. The tasters were taken to individual booths and received: evaluation form, white disposable cup with mineral water, white disposable dish with water cracker biscuit and white disposable cup with coffee powder (Stone & Sidel, 1993). Samples were offered in the form of complete blocks, only once, in three white disposable cups identified with three random digits: 253, 147 and 521. The appearance, odor, juiciness, flavor and tenderness properties were evaluated and measured through scores, on a 9-point unstructured hedonic scale, assigning the following scores: 1 (extremely disliked), 2 (disliked a lot), 3 (regularly disliked), 4 (slightly disliked), 5 (indifferent), 6 (slightly liked), 7 (regularly liked), 8 (liked a lot) and 9 (extremely liked). At the end of the test, it was asked which sample the taster would buy to consume.

Data of body and carcass characteristics were tested by analysis of variance and the mean values were compared by Tukey's test at 5% probability. For the sensory analysis data, a randomized block design was adopted, whereby each taster was considered as a block. Pearson correlations were estimated between some measurements of the animal and the cold carcass. All statistical procedures were run in the SAEG software.

Results and discussion

The replacement of corn silage (CS) with spineless cactus combined with Tifton 85 hay (CT) or sugarcane bagasse (CB) did not influence ($p > 0.05$) body length, withers height, chest circumference or conformation of animals (Table 2).

Except for chest width, larger ($p < 0.05$) in animals fed CT compared to CT, the body measurements of sheep were similar between treatments. Pinto et al. (2011) reported no effect for the addition of spineless cactus on the body measurements of Santa Inês sheep. Probably, the proximity ($p > 0.05$) in the values of slaughter weight of the animals subjected to the treatments contributed to the homogeneity in the linear measurements of body circumference of the animals.

The Santa Inês lambs had an average body length of 63.95 cm, similar to the 63.7 cm observed by Sousa et al. (2009), when examined the body measurements of Santa Inês animals slaughtered with an average body weight of 30 kg. According to Gusmão Filho et al. (2009), more developed animals tend to obtain greater body length. However, long animals are not always the best conformed, since the conformation is evaluated by the relationship between muscle profiles, and according to Silva et al. (2016), short, wide and compact carcasses are recommended.

Table 2. Body measurements of Santa Inês lambs fed corn silage, spineless cactus combined with Tifton 85 hay or spineless cactus combined with sugarcane bagasse.

	Corn silage	Spineless cactus +hay	Spineless cactus +bagasse	CV (%)	P-value
Body weight at slaughter (kg)	29.73	35.07	31.78	14.25	0.12
Body length (cm)	63.14	64.86	63.86	5.78	0.69
Withers height (cm)	66.00	66.71	65.71	3.04	0.63
Chest width (cm)	20.14b	21.71a	20.43ab	5.32	0.03
Croup height (cm)	68.71	68.14	67.57	3.01	0.59
Croup width (cm)	18.00	18.43	18.71	8.22	0.67
Chest depth (cm)	30.86	32.29	31.29	5.38	0.29
Chest circumference (cm)	74.14	78.57	77.29	5.6	0.16
Thigh circumference (cm)	34.43	39.00	37.00	9.57	0.07
Conformation (cm)	3.14	3.64	3.07	13.28	0.05

Mean values followed by different letters, in the same row, are significantly different by Tukey's test ($p > 0.05$).

Values of 66.14 cm and 68.14 cm for withers and croup height observed in this experiment were higher than the 59.45 cm and 61.18 cm observed by Moreno et al. (2010b), in Ile de France lambs. This defines Santa Inês animals as waders when compared to other breeds specialized for meat production.

The cold carcass weight (CCW) was influenced ($p < 0.05$) by the experimental diets, but the carcass measurements did not differ between treatments (Table 3).

Table 3. Carcass characteristics of Santa Inês lambs fed corn silage, spineless cactus combined with Tifton 85 hay or spineless cactus combined with sugarcane bagasse.

	Corn silage	Spineless cactus + hay	Spineless cactus + bagasse	CV (%)	P-value
Cold carcass weight (kg)	13.66b	17.41a	15.41ab	16.67	0.04
External carcass length (cm)	56.28	58.00	56.00	5.83	1.13
Internal carcass length (cm)	62.71	65.71	63.14	4.49	0.13
Leg length (cm)	38.00	39.71	40.28	8.62	0.89
Croup width (cm)	23.86	25.36	24.86	9.69	0.87
Chest width (cm)	16.86	18.14	17.43	7.06	0.18
Chest depth (cm)	28.00	29.14	28.57	5.75	0.90
Croup perimeter (cm)	58.43	61.00	59.86	5.39	0.35
Leg circumference (cm)	34.00	35.71	34.28	9.29	1.20
Chest circumference (cm)	68.00	72.64	71.43	5.40	0.08
Conformation	1.71b	2.71[a]	2.71a	24.82	0.03
Carcass compactness index (kg cm^{-1})	0.22	0.26	0.24	14.30	0.06

Mean values followed by different letters, in the same row, are significantly different by Tukey's test ($p > 0.05$).

Lambs receiving spineless cactus combined with Tifton 85 hay had a higher CCW (17.41 kg) compared to those fed corn silage (13.66 kg). The average CCW value of the animals evaluated in this experiment was 15.49 kg, similar to the 14.85 kg reported by Pinto et al. (2011), who analyzed the inclusion of spineless cactus in the Santa Inês sheep diet. Carcasses with higher CCW were also the better conformed ($p < 0.05$), these findings corroborate data of Oliveira et al. (2018) in Santa Inês lambs at two slaughter ages.

High and positive correlations were detected between body measurements and body weight at slaughter (Table 4). These results are in line with Fernandes Junior et al. (2015), with data obtained from Santa Inês lambs.

Chest depth ($R^2 = 0.76$), chest circumference ($R^2 = 0.77$) and in vivo conformation ($R^2 = 0.83$) were strongly and positively correlated with body weight at slaughter (BWS) of Santa Inês sheep. These same measures were also highly correlated with the cold carcass weight, with correlation coefficients (R^2) of 0.82; 0.81 and 0.88 for chest depth, chest circumference and in vivo conformation, respectively. The results are in line with those found by Pinheiro and Jorge (2010), in which the chest circumference had a positive and high correlation with body weight at slaughter and cold carcass weight. That is, several body measures of high and positive correlation with body weight at slaughter indicate that these variables can be used as predictors of animal performance.

Several studies found a high and positive correlation between body measurements and body weight at slaughter (Fernandes Junior et al., 2015; Silva et al., 2016; Souza et al., 2014). In these studies, the body measurement with the highest correlation with body weight at slaughter was the chest circumference, and consequently this measurement was the one that best predicted body weight at slaughter.

Table 4. Pearson correlation coefficients between body and carcass measurements of Santa Inês lambs fed corn silage, spineless cactus combined with Tifton 85 hay or spineless cactus combined with sugarcane bagasse.

	BWS	CHW	CRW	CD	CC	TC	IVC	CCW	ECL	ICL
Body measurements										
BWS	1.00									
CHW	0.68^{***}	1.00								
CRW	0.68^{***}	0.32^{NS}	1.00							
CD	0.76^{***}	0.47^{*}	0.50^{**}	1.00						
CC	0.77^{***}	0.66^{***}	0.36^{*}	0.81^{***}	1.00					
TC	0.57^{***}	0.49^{**}	0.26^{NS}	0.44^{*}	-	1.00				
IVC	0.66^{***}	0.72^{***}	0.12^{NS}	0.57^{***}	0.73^{***}	0.69^{***}	1.00			
Carcass measurements										
CCW	0.85^{***}	0.82^{***}	0.41^{*}	0.60^{***}	0.81^{***}	0.73^{***}	0.79^{***}	1.00		
ECL	0.58^{***}	0.64^{***}	0.24^{NS}	0.25^{NS}	0.33^{NS}	0.45^{*}	0.45^{*}	0.58^{***}	1.00	
ICL	0.81^{***}	0.68^{***}	0.44^{*}	0.66^{***}	0.62^{***}	0.39^{*}	0.63^{***}	0.73^{***}	0.66^{***}	1.00
CRWC	0.46^{*}	0.34^{NS}	0.43^{*}	0.13^{NS}	0.20	0.24^{NS}	0.09^{NS}	0.36^{NS}	0.51^{**}	0.55^{*}
CHWC	0.66^{***}	0.53^{**}	0.38^{*}	0.37^{*}	0.57^{***}	0.65^{***}	0.76^{NS}	0.73^{***}	0.46^{*}	0.67^{***}
CDC	0.61^{***}	0.39^{*}	0.11^{NS}	0.72^{***}	0.75^{***}	0.58^{***}	0.69^{NS}	0.66^{***}	0.36^{NS}	0.59^{***}
CPC	0.83^{***}	0.65^{***}	0.55^{**}	0.55^{***}	0.73^{***}	0.62^{***}	0.61^{NS}	0.83^{***}	0.53^{*}	0.75^{***}
LC	0.58^{***}	0.39^{*}	0.35^{NS}	0.31^{NS}	0.44^{*}	0.23^{NS}	0.32^{NS}	0.47^{*}	0.39^{*}	0.52^{**}
CCC	0.83^{***}	0.66^{***}	0.38^{*}	0.73^{***}	0.90^{***}	0.71^{***}	0.76^{NS}	0.92^{***}	0.40^{*}	0.70^{***}
CC	0.49^{***}	0.64^{***}	0.23^{NS}	0.48^{*}	0.69^{***}	0.48^{**}	0.44^{NS}	0.69^{***}	0.33^{NS}	0.49^{**}

BWS- Body weight at slaughter (kg); CHW- Chest width (cm); CRW- Croup width (cm); CD- Chest depth (cm); CC- Chest circumference (cm); TC- Thigh circumference (cm); IVC- *In vivo* conformation; PCF- Cold carcass weight; CEC- External carcass length; CIC- Internal carcass length; CRWC- Croup width; CHWC- Chest width; CDC- Chest depth; CPC- Croup perimeter; LP- Leg circumference; CCC- Chest circumference; CC- Carcass conformation.

The diet influenced the sensory characteristics of the meat of Santa Inês lambs, so that the meat of animals fed corn silage received the lowest ($p < 0.05$) scores of odor and flavor (Table 5).

Table 5. Acceptance test of meat of Santa Inês lambs fed corn silage, spineless cactus combined with Tifton 85 hay or spineless cactus combined with sugarcane bagasse.

	Corn silage	Spineless cactus + hay	Spineless cactus + bagasse	CV (%)	P-value
Appearance	7.37	7.14	7.39	17.40	0.53
Odor	6.53b	7.25a	7.71a	24.26	0.00
Juiciness	7.04	7.00	6.86	24.41	0.86
Flavor	6.53b	7.43a	7.22a	22.18	0.00
Tenderness	7.57	7.86	7.37	19.99	0.21

Mean values followed by different letters, in the same row, are significantly different by Tukey's test ($p > 0.05$).

Corn silage - an anaerobic fermentation product - contains a high amount of lipids modified by fermentation in the silo (hydrogenation), branched-chain volatile fatty acids and skatol (Schreurs et al., 2008). Skatol is considered as the main responsible for the rejection of sheep meat (Ferrão et al., 2009). Analyzing the replacement of corn silage with sugarcane, Leão et al. (2012) found a higher skatol content in the meat of animals fed silage (0.79 μg g^{-1} fat) compared to those fed sugarcane (0.38 μg g^{-1} fat).

In the present study, the lower scores attributed by the tasters to odor (6.53) and flavor (6.53) of meat from lambs receiving corn silage, indicate that the tasters slightly liked the meat of these animals. In the space for observation in the evaluation form, some tasters pointed out that the sample from animals fed corn silage showed a more intense sheep flavor and aroma, reflecting the lower scores for these characteristics. Madruga et al. (2005) also observed a higher intensity of sheep odor in the meat of animals fed corn silage.

The properties of appearance, juiciness and tenderness of the meat were not influenced ($p > 0.05$) by the replacement of corn silage with spineless cactus combined with Tifton 85 hay or sugarcane bagasse. These organoleptic properties determine the taste that causes acceptance or refusal by the consumer (Costa et al., 2011). In this context, the tasters, when asked which samples they would intend to buy and consume, about 43% indicated the meat of animals fed Tifton 85 (Figure 1).

Therefore, the purchase intention data shows that consumers prefer the meat obtained from animals raised in systems with more traditional foods (spineless cactus and Tifton hay) possibly because they affect less the sensory quality of sheep meat. Abreu et al. (2019) also found that the inclusion of spineless cactus in sheep diet increases the intention of purchasing meat from these animals.

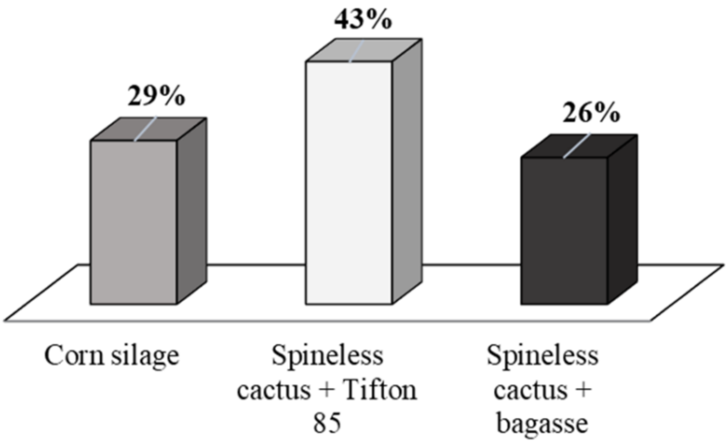

Figure 1. Purchase intention of Santa Inês sheep meat fed corn silage, spineless cactus combined with Tifton 85 hay or spineless cactus combined with sugarcane bagasse.

Conclusion

Spineless cactus combined with sugarcane bagasse or Tifton 85 hay can replace corn silage in diets for Santa Inês sheep in confinement, without compromising the sensory quality of the meat and the carcass characteristics. Furthermore, it provides superior taste and odor.

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