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Performance and carcass yields of deslaned lambs fed levels of spineless cactus as a substitute for Tifton hay

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Abstract

The aim of this research was to evaluate the effects of including Miúda spineless cactus (*Nopalea cochenillifera* Salm Dyck) as a substitute for Tifton-85 hay (Cynodon dactylon) on the performance and carcass yield of lambs finished in confinement. An experiment was conducted with 24 Santa Inês lambs, with an average age of 119 ± 29.89 days and an average initial weight of 14.64 ± 2.28 kg. The animals were slaughtered after 89 days in confinement. Four diets were formulated, containing four inclusion levels of spineless cactus 0%, 6.5%, 16.63%, and 35.10 as a substitute for Tifton-85 hay. As the amount of spineless cactus in the diet increased, the lambs had higher dry matter consumption, water consumption, final weight, daily weight gain, feed efficiency, and body score. The diet with the highest inclusion of spineless cactus provided the highest gross margin. A level of 35.10% spineless cactus in the diet is recommended for the confinement of lambs.

Keywords: dry matter intake; daily weight gain; *Nopalea cochenillifera* Salm Dyck; Santa Inês; water intake.

Practical Application: Alternative feed for ruminants during the dry season in the arid and semiarid regions.

1 INTRODUCTION

In arid and semiarid regions, the dry season represents a major obstacle for animal production due to the scarcity of food and the decrease in the nutritional value of forage plants, leading to the need to confine animals during dry periods, which increases the cost of production. To mitigate the effect of food shortages during these periods of drought, the identification of alternative forage crops is essential. Such as spineless cactus, which is characterized by its good development and ability to meet the nutritional demands of livestock and favor meat production (Porto Filho et al., 2020).

Spineless cactus is a food rich in mucilage, with significant levels of minerals, mainly calcium (2.0–5.7%), potassium (1.5–2.58%), magnesium (1.3–1.7%), and phosphorus (0.1–0.6%) (Wanderley et al., 2002). It also has high levels of nonfibrous carbohydrates and low levels of neutral detergent fiber, making it an important alternative food in semiarid regions (Barbosa et al., 2017). The main limiting factors for spineless cacti's use in ruminants comprise its low levels of dry matter (DM) (9–12%) and crude protein (4.9%) (Cavalcanti et al., 2008), but it has a high content of water (80–90%) and organic matter (93%; DM basis) (Cordova-Torres et al., 2022). A key benefit of using spineless cactus is its provision of soluble carbohydrates, which positively contribute to the ruminal environment. To guarantee the effective functioning of ruminal activities, such as rumination, ruminal movement, ruminal content homogenization, and salivary secretion; a very important factor is spineless cacti's association with fibrous foods (Bispo et al., 2007).

The spineless cactus (Nopalea cohenillifera Salm Dyck) has been considered a "Life Bank" due to its characteristics as it provides water, feed, and food for animals and humans in areas with water scarcity (Ben Salem & Smith, 2008). In general, daily intake for sheep and goats is estimated at ± 3 L animal^{-1} (Araújo et al., 2010; Cordova-Torres et al., 2022). By offering diets with up to 42% spineless cactus silage and intermittent supply (every 48 hours) to goats. Several studies have evaluated the effect of water intake (WAI) by animals when using spineless cactus as the feed ingredient, which showed a reduction in drinking WAI when a certain level of spineless cactus was included in the diet (Albuquerque et al., 2020; Andrade-Montemayor et al., 2011; Cordova-Torres et al., 2022; Costa et al., 2012).

The aim of this study was to assess the animal performance and carcass yields of Santa Inês lambs finished in confinement, fed spineless cactus as a substitute for Tifton hay.

2 MATERIAL AND METHODS

2.1 Location of the experiment

This experiment was performed at the Centre of Agricultural Sciences of the Universidade Federal de Alagoas (UFAL),

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latitude 9º27′ S and longitude 3º27′W, at an average elevation of 127 m above sea level. The minimum average temperature is 23.9°C, and the maximum temperature is 33.1°C, with a relative humidity of 25.8%.

The Commission of Ethics approved this research according to the Use of Animals of the UFAL, with approval number 56/2016.

2.2 Animals

A total of 24 whole Santa Inês lambs were used, with an average age of 119 ± 29.89 days and an average initial weight of 14.64 ± 2.28 kg. They were confined for 89 days in individual stalls measuring 1.12 × 1.55 m with cemented floor and individual feeders and drinkers. All the stalls were cleaned daily.

The period of adaptation to the stalls and diets was 14 days, during which the animals were identified with ear tags, vaccinated against clostridiosis, and checked for eimeriosis (sulfaquinoxaline sodium) for 3 days. The animals were also wormed (ivermectin 1%) once on the first day of confinement and again 15 days later.

2.3 Diet

Four diets were formulated based on the National Research Council (NRC) (2007), for daily gains of 250 g/day, containing four levels of inclusion of spineless cactus cultivar Miúda 0%, 6.5%, 16.63%, and 35.10% as a substitute for Tifton hay. Ground maize, soya and wheat bran, urea, soya oil, and mineral supplement were used as concentrate ingredients. The basis of the roughage was Tifton-85 hay, ground in a forage machine to reduce it to particles smaller than 5 cm. The spineless cactus was also passed through a forage machine. To calculate its composition, we used data from a table published in the literature, but for the spineless cactus ingredient, we used data from analyses carried out at UFAL's Applied Enzymology and Bromatology Laboratory (Table 1).

During the adaptation period, the lambs received the diets *ad libitum*, after which the animals were weighed and the experimental period began. During this period, the diet was offered twice a day, based on 5% of live weight, and adjusted according to the previous day's leftovers (10%), in order to guarantee the animals' voluntary consumption.

2.4 Dry matter and water intake

The diet and leftovers were collected and weighed daily to calculate dry matter intake (DMI).

WAI was determined by quantifying the supply and surplus in 24-hour periods over 13 weeks. This observation began at 8 am, with 5 L of water being offered to each animal in plastic containers of the same shape. At 8 am the following day, the surplus was quantified to estimate consumption in liters over 24 h, and this procedure was repeated three times a week. Every 14 days, the animals were weighed to adjust intake.

2.5 Measurements

After 89 days of confinement, the animals were weighed to obtain their final live weights (FLWs) without fasting and then subjected to a period of fasting on solids with a water diet for 16 hours, after which they were weighed again to obtain their live weight at slaughter (LWS), which was used to calculate average daily weight gain (ADWG) and feed efficiency (FE).

Before slaughter, the body score was assessed by two trained examiners according to the methodology described by Cezar and Souza (2007). A range of 1–5 was adopted, varying by 0.5

Table 1. Ingredients proportions and chemical compositions of the experimental diets with spineless cactus.

Ingredients (g kg^{-1} DM)	Spineless cactus inclusion (%DM)			
	0.0	**6.5**	**16.63**	**35.10**
Spineless cactus	0.0	65	166.3	351.0
Corn bran	112.5	193.0	224.9	0.0
Soybean meal	152.5	141.0	225.0	337.0
Farelo de trigo	0.0	0.0	0.0	297.0
Tifton hay	700.0	573.0	368.8	0.0
Soy oil	30.0	13.0	0.0	0.0
Mineral mixture[1]	5.0	5.0	5.0	5.0
Urea+enxofre	0.0	10.0	10.0	10.0
Chemical composition				
Dry matter, DM (g kg^{-1} as fed)	891.4	840.3	761.3	623.6
Crude protein, CP (g kg^{-1} as DM)	147.3	168.1	197.1	253.9
Ether extract, EE (g kg^{-1} as DM)	48.3	33.5	21.7	21.8
Neutral detergent fiber, NDF (g kg^{-1} as DM)	589.5	515.9	398.2	272.1
Nonfibrous carbohydrates, NFC (g kg^{-1} as DM)	181.6	270.9	370.4	430.0
Mineral matter, MM (g kg^{-1} as DM)	63.4	62.5	65.8	81.4
Metabolizable energy (Mcal kg^{-1} DM)	2.44	2.43	2.51	2.61
Relação Volumoso:Concentrado	70:30	64:36	53:47	35:65

[1]Assurance levels (per kilogram of active elements): 120 g of calcium, 87 g of phosphorus, 147 g of sodium, 18 g of sulfur, 590 mg of copper, 40 mg of cobalt, 20 mg of chromium, 1,800 mg of iron, 80 mg of iodine, 1,300 mg of manganese, 15 mg of selenium, 3,800 mg of zinc, 300 mg of molybdenum, and maximum 870 mg of fluoride.

points: score 1 – very thin or emaciated animals; score 2 – thin animals; score 3 – moderate animals; score 4 – fat animals; and score 5 – very fat or obese animals.

2.6 Economic analyses

The gross margin calculations were based on the total weight gain during the confinement period, the price per kilogram in the region, the total DM consumption, the price per kilogram of DM, and the costs of vaccines and medicines (CVM). For spineless cactus, the cost practiced in the Alagoas hinterland was 5,000.00 R$/ha with an average production of 300 t/ha of green matter. These calculations were adapted from Véras et al. (2005), and the gross margin was determined using Equation 1:

$$\text{Gross margin} = \text{total weight gain} \times 5{,}00 - (\text{DMItotal} \times \text{Price/kg diet}) - \text{CVM} \quad (1)$$

5,00: price (R$)/ kg of live lamb in the region and neighboring towns;

DMItotal: DMI total;

CVM: costs of vaccines and medicines.

2.7 Statistical analysis

The design used was randomized blocks, using the weights of the animals to form the blocks, with four treatments and six replicates.

The data were subjected to regression analysis using PROC REG in SAS (SAS Institute, Inc., 2001).

3 RESULTS

DMI, regardless of the form in which it was expressed, increased linearly as spineless cactus was included in the diet. Thus, for each percentage unit of spineless cactus added to the diet, DMI increased by 0.0023 kg/day or 2.3 g/day (Table 2).

WAI by sheep in the three forms in which it was expressed (Table 2) increased linearly as the inclusion of spineless cactus increased. In terms of WAI in liters per kilo of DMI, there was a linear decrease as the amount of hay replaced by spineless cactus increased. Comparing the diet without the inclusion of spineless cactus with the diet with the highest level of spineless cactus inclusion, it can be seen that the animals in the treatment without spineless cactus consumed 61.16% more water than the animals in the 35% spineless cactus treatment. This shows the importance of spineless cactus as a source of water, which is a limiting element for livestock in semiarid regions.

As the replacement of Tifton hay with spineless cactus increased, so did energy intake. Table 1 shows that as spineless cactus enters the diet, the proportion of neutral deterget fiber (NDF) decreases, showing a reduction of around 53.84% from the control to the treatment with the maximum inclusion of spineless cactus. The proportion of nonfibrous carbohydrates (NFCs) increased by 136.78% when comparing the 0% diet with the 35.1% spineless cactus diet, making the diet more digestible, which led to an increase in DMI and consequently an increase in energy intake.

Final live weight, ADWG, LWS, FE, and body score showed linear growth as spineless cactus was added to the diet (Table 3). This behavior can be explained by the decrease in NDF content

Table 2. Dry matter intake (DMI), water intake (WAI), and metabolizable energy intake (MEI) by Santa Inês sheep as a function of the inclusion of spineless cactus cv. Miúda.

Intake	Spineless cactus inclusion (%DM)				CV (%)	R^2
	0.0	6.5	16.63	35.10		
Dry matter (kg day^{-1})	0.54	0.71	0.73	0.78	13.74	60.81[1]
Dry matter (%PC)	3.22	3.60	3.73	3.80	11.05	69.60[2]
Dry matter ($PV^{0,75}$)	65.15	75.43	78.23	80.39	11.32	68.99[3]
Water (L day^{-1})	1.62	2.16	2.23	3.21	32.23	94.61[4]
Water ($PC^{0,75}$)	200.60	238.15	247.91	333.95	26.26	95.92[5]
Water (% PC)	10.02	11.47	11.94	15.78	25.15	96.01[6]
Water (L kg^{-1} DM)	3.32	2.72	2.19	2.06	20.42	78.64[7]
Metabolizable energy (Mcal kg^{-1} DM)	1.33	2.12	2.78	4.29	16.16	99.26

[1]Y: 0.6081 + 0.0056x; [2]Y: 3.3823 + 0.0141x; [3]Y: 69.472 + 0.366x; [4]Y: 1.6927 + 0.0421x; [5]Y: 202.67 + 3.6051x; [6]Y: 10.012 + 0.1573x; [7]Y: 3.0568 - 0.0333x; [8]Y: 1.4407 + 0.0817x; CV: coefficient of variation.

Table 3. Performance and carcass weights of Santa Inês sheep as a function of the inclusion of Spineless cactus cv. Miúda.

Variable	Spineless cactus inclusion (%DM)				CV (%)	R^2
	0.0	6.5	16.63	35.10		
Final live weight (kg)	21.20	27.73	30.80	35.83	9.99	90.84[1]
Average daily weight gain (kg)	0.07	0.14	0.18	0.24	17.61	92.75[2]
live weight at slaughter (kg)	19.68	26.03	28.38	32.40	9.94	87.09[3]
Feed efficiency (%)	13.74	20.58	25.38	30.33	12.04	90.52[4]
Body score	2.0	2.8	3.3	3.7	9.39	85.83[5]

[1]Y: 23.34 + 0.3809x; [2]Y: 0.0922 + 0.0045x; [3]Y: 21.899 + 0.3245x; [4]Y: 16.093 + 0.4406x; [5]Y: 2.3047 + 0.0443x; CV: coefficient of variation.

and the increase in total digestible nutrients as the replacement of Tifton hay with spineless cactus increased, which led to higher DMI with a greater supply of nutrients and consequently better animal performance.

In terms of ADWG, the diet with the highest spineless cactus inclusion was 242.85% higher than the diet with the lowest spineless cactus substitution. As spineless cactus was added to the diet, the bulk component increased, resulting in a decrease in the diet's NDF content (Table 1); associated with these changes, LWS increased linearly. The body score increased linearly as the replacement of Tifton hay with spineless cactus increased. This was probably due to the difference in slaughter weight, which showed the same behavior (Table 3).

It can be seen that the diet with the highest level of spineless cactus inclusion was 219.3, 47.4, and 69 % higher than the 0% spineless cactus inclusion diet for the variable weight gain, diet cost kg/DMI, and final lamb price, respectively (Table 4). The inclusion of spineless cactus in the diet led to a difference in the gross margin, with positive values for diets with spineless cactus inclusion and a negative value for diets in which spineless cactus was not substituted for Tifton hay. As the substitution of Tifton hay for spineless cactus increased, there was an increase in the gross margin, reflecting the lower cost of spineless cactus compared to Tifton hay. The economic results indicated that the 35.10% level of spineless cactus inclusion was the most advantageous and effective.

4 DISCUSSION

The inclusion of 35% spineless cactus did not meet the DMI recommended by the NRC (2007) for lambs (830 g day^{-1} of DM). These results were also observed in other studies (Albuquerque et al., 2020; Batista et al., 2020; Cordova-Torres et al., 2022), which found a reduction in DMI when levels were above 50%. The DM of spineless cactus is included in the diet, justifying the distension of the digestive tract due to the high water content and thus limiting feed consumption (Van Soest et al., 1991).

DMI is one of the factors that most affect production performance, as 60–90% of the variation in animal performance is due to DMI and only 10–40% is due to diet digestibility (Savietto et al., 2014). Evaluating the effect of replacing elephant grass hay with spineless cactus (Opuntia ficus indica, Mill) in sheep, Bispo et al. (2007) observed similar behavior, in which DMI increased linearly with the replacement of elephant grass hay by spineless cactus in the diet, with average DM values of 640.31, 810.52, 1,098.65, 1,138.95, and 1,145.35 (g/day); 2.28, 2.97, 3.86, 4.11, and 3.89 (%PV); and 52.29, 61.87, 88.88, 93.84, and 90.47 (g/PV0.75) for the levels (0, 14, 28, 42, and 56) of substitution. The spineless cactus has a high rumen digestion rate, and the DM is degraded quickly, favoring a higher passage rate and, consequently, consumption similar to that of concentrates (Muniz et al., 2011).

According to Cordova-Torres et al. (2022), the 50% and 70% DM content of spineless cactus decreased the DM and other fractions due to the high proportion of spineless cactus and consequently the high moisture content (approximately 88% of the fresh weight), which therefore occupies a considerable volume in the rumen (Cordova-Torres et al., 2015). Another factor that may have influenced the DMI was the decrease in the diet's NDF content with the inclusion of spineless cactus. When low-quality diets are provided (high NDF content), feed consumption occurs until the maximum capacity of the gastrointestinal tract is reached. In this way, it can be inferred that diets with higher levels of NDF, i.e., with less spineless cactus, limited the animals' consumption because the rumen's physical capacity had been reached.

According to the NRC (2007), water requirements can be met from three different sources: voluntary water consumption, WAI from feed, and water from the metabolism of nutrients in the body. The inclusion of spineless cactus in diets leads to an increase in feed water consumption due to its high moisture content. Araújo et al. (2010) and Neto et al. (2016) stated that spineless cactus can be an important source of water for animals in times of water scarcity.

The protein content (Table 1) may have led to higher water consumption by the animals. Berchielli et al. (2006) stated that protein-rich foods often result in a greater demand for water due to the calorific increase of the protein and the elimination of metabolic waste.

According to Cordova-Torres et al. (2022), the inclusion of 30% DM of spineless cactus replacing Tifton grass hay in lamb diet improved DMI, digestibility, metabolic body water, average daily gain, feeding conversion, and feedlot time compared to control diet with lambs receiving drinking water *ad libitum* without spineless cactus. The restriction of drinking water (voluntary) in lamb fed with diet above 30% DM of spineless cactus also did not affect the performance. Thus, the spineless cactus, in addition to a feed supplement, can be used as only water resource during 90 days of feedlot

According to Cordova-Torres et al. (2022), the ADWG was also higher in lambs that received 30% spineless cactus, but the inclusion of 50% and 70% in the total DM of spineless cactus promoted similar performance.

The animals in the 0% spineless cactus inclusion treatment were classified as lean, while the animals in the 35.10% spineless cactus treatment were classified as moderate according to the classification described by Cezar and Souza (2007).

Table 4. Economic result (R$/animal) due to the inclusion of spineless cactus cv. Miúda.

Variable	Spineless cactus inclusion (%DM)			
	0.0	**6.5**	**16.63**	**35.10**
Weight gain (Kg)	6.63	12.87	16.33	21.17
Diet kg DM (R$)*	0.84	0.75	0.67	0.57
Initial lamb price (R$)	72.83	74.33	72.33	73.33
Final lamb price (R$)	106.00	138.67	154.00	179.19
Vaccine and medication (R$)	2.06	2.11	2.05	2.09
Gross margin/lamb (R$)	–9.16	15.03	35.55	64.13

*Maize bran: R$0.75; Soya bean meal: R$0.99; Wheat bran: R$0.70; Tifton hay: R$0.70; Palm oil: R$0.016; Soya bean oil: R$3.31 liter; Urea: R$1.24; Ammonium sulfate: R$0.72; Mineral salt: R$2.40.

5 CONCLUSIONS

The inclusion of 35.10% spineless cactus to replace Tifton hay in the diet of lambs leads to higher DMI, daily weight gain, slaughter weight, FE, and body score compared to the control diet. Thus, spineless cactus, as well as a feed supplement, can be used as the only water resource during 89 days of confinement.

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