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Carcass characteristics of 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 forage palm in the diet of lambs finished in confinement on carcass characteristics. A total of 24 Santa Ines lambs were used, with an average age of 119 ± 30 days and an average initial weight of 14.64 ± 2.28 kg. All the animals were slaughtered after 89 days in confinement. Four diets were formulated, containing four inclusion levels of Palma Miúda (*Nopalea cochenillifera* Salm-Dyck): 0, 6.5, 16.63, and 35.10% as a substitute for Tifton-85 (*Cynodon dactylon*) hay. The design used was randomized blocks. The variables final live weight, hot carcass weight, cold carcass weight, hot carcass yield, cold carcass yield, biological yield, loin eye area, subcutaneous fat thickness, grid rule measurement, carcass compactness index, the weights of the neck, palette, loin, rib and leg cuts, and the yields of the loin and rib cuts, showed increasing linear behavior as the amount of Palma Miúda in the diet increased, but the yields of the neck, palette, and leg cuts decreased linearly. Diets with higher palm inclusion provide carcasses with better subcutaneous fat thickness, loin eye area, and carcass compactness index, while also providing higher weights of commercial cuts and lower yields of palette and leg cuts.

Keywords: finishing; loin eye area; regional cuts; Santa Inês.

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

1 INTRODUCTION

In arid and semi-arid 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. In order 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).

The spineless cactus belongs to the *Cactaceae* family and has around 130 genera and 500 species, of which 300 are from the *Opuntia* genus (Mohamed-Yasseen et al., 1996), which, together with the *Nopalea* genus, make up the most important group due to their diversity of use (Feugang et al., 2006). The climatic circumstances of semi-arid regions make spineless cacti a strategic food when the growth of other forage plants is limited, especially in conditions of low rainfall (Cavalcanti et al., 2008).

Some of the palm's nutritional characteristics, such as the content of non-fibrous carbohydrates (58%) and neutral detergent fiber (63.27%) and its dry matter digestibility coefficient of around 67% (Lima et al., 2019), make it an important food alternative (Cordova-Torres et al., 2022) and a potential source of energy for ruminants (Cordova-Torres et al., 2022; Lima et al., 2019; Porto Filho et al., 2020). The nutritional value of palm varies according to the species (Misra et al., 2006). Regardless of gender, the palm has low levels of dry matter (11.69 ± 2.56%), crude protein (4.81 ± 1.16%), neutral detergent fiber (26.79 ± 5.07%), and acid detergent fiber (18.85 ± 3.17%), but contains good levels of total carbohydrates (81.12 ± 5.9%), non-fiber carbohydrates (58.55 ± 8.13%), and mineral matter (12.04 ± 4.7%) (Atti et al., 2006).

The spineless cactus (*Nopalea cochenillifera* 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% forage spineless cactus silage and intermittent water supply (every 48 h) to goats. Several studies have evaluated the effect of water intake by animals when using spineless cactus as a feed ingredient, which showed a reduction in drinking water intake 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 research was to evaluate the effects of including forage palms in the diet of lambs finished in confinement on carcass characteristics.

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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), latitude 9°27′ S and longitude 3°27′ 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 Universidade Federal de Alagoas, 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 a 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 supplements 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 Measurements

The animals were weighed every 14 days to adjust consumption. After 89 days of confinement, the animals were weighed to obtain their final live weights without fasting and then subjected to a 16-h fasting period on solids with a water diet, after which they were weighed again to obtain their live weights at slaughter (LWS).

The slaughter process began with a stunning brain concussion, followed by bleeding, skinning, and evisceration. The gastrointestinal tract was removed, weighed, and, after removing its contents, weighed again to determine the empty gastrointestinal tract. Empty body weight (EBW) was determined, defined as the LWS minus the sum of the empty gastrointestinal contents (EGC), urine, and bile juice: EBW = LWS – EGC) + urine + bile juice.

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
Non-fibrous 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} as DM)	2.44	2.43	2.51	2.61
Volume:concentrate ratio	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.

After removing the head and limb ends, the carcasses were weighed to obtain the hot carcass weight (HCW), thus making it possible to calculate the hot carcass yield (HCY = HCW/LWS × 100) and the biological or true yield (BY = HCW/EBW × 100).

The carcasses were then transported to a cold room at ± 4 °C, where they were kept for 24 h, hanging by their tendons from hooks suitable for keeping the tarsometatarsal joints an average of 17 cm apart. At the end of this phase, based on the weight of the cold carcass, the percentage of weight loss due to cooling was determined (WLC = PCQ-PCF)/PCQ × 100, where CCW is the cold carcass weight, as well as the cold carcass yield (CCY = CCW/LWS) × 100 and the carcass compactness index (CCI, kg/cm = CCW/internal length of the cold carcass).

After 24 h at ± 4°C in the cold room, the carcasses were weighed, and the CCW was obtained. The carcasses were then split lengthways at the midline into two antineros. The internal length of the carcass (ILC) was measured on the right mid-carcass using a tape measure, and this measurement was used to determine the carcass compactness index (CCI = CCW – ILC) (Osório et al., 1998).

On the right half-carcass, a transverse cut was also made between the 12th and 13th ribs, exposing the transverse section of the longissimus dorsi muscle, after which the outline of the muscle was traced on a transparent plastic sheet. Using a ruler, the maximum width (A) and maximum depth (B) of the muscle were measured. These measurements were used to determine the loin eye area, according to the formula LEA = (A/2 × B/2) π (Silva Sobrinho, 1999).

Also in the Longissimus dorsi, using a caliper, the thickness of the covering fat was measured over the section of muscle (between the last thoracic and first lumbar vertebrae) at two-thirds of the total length of the loin eye area (Muller, 1980).

The GR (grade rule) measurement determines the amount of subcutaneous fat present in the carcass. It was determined by the depth of the fat on the 12th rib at a distance of 11 cm from the midline of the lumbar using a caliper.

The right side was then sectioned into five anatomical regions according to Colomer-Rocher et al. (1988), which were weighed individually once separated: leg: bone base comprising the iliac region (ilium), ischium, pubis, sacral vertebrae, the first two coccygeal vertebrae, femur, tibia, and tarsus, obtained by cutting perpendicular to the spine between the last lumbar vertebra and the first sacral vertebra; loin: comprises the region of the lumbar vertebrae, obtained perpendicular to the spine, between the 13th dorsal-first lumbar and last lumbar-first sacral vertebrae; ribs: comprises the 13 thoracic vertebrae, with the corresponding ribs and the sternum; palette: region comprising the scapula, humerus, radius, ulna, and carpus; and neck: refers to the seven cervical vertebrae; it is obtained by making an oblique cut between the seventh cervical and first thoracic vertebrae.

2.5 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 was subjected to regression analysis using PROC REG in SAS (SAS Institute, 2001).

3 RESULTS

Replacing Tifton hay with spineless cactus leads to an increase in non-fiber carbohydrate content in the diet (Table 1), which leads to greater tissue accumulation, reflected in higher final live weight, LWS, EBW, HCW, and CCW (Table 2). The content of the gastrointestinal tract decreased linearly with the inclusion of spineless cactus, which was to be expected since the higher the concentration of spineless cactus in the diet, the lower the percentage of fiber (Table 1). As the diet becomes more digestible, the rate of passage increases, and, consequently, the food remains in the gastrointestinal tract for less time during the fasting period.

Replacing the hay with spineless cactus is a change in the volume:concentrate ratio and consequently a reduction in the neutral detergent fiber content and an increase in non-fibrous carbohydrates. In addition, the protein content increased, and the fat content decreased. The diets were isoenergetic. Biological, hot, and cold carcass yield showed an increasing linear behavior

Table 2. Carcass characteristics of Santa Ines lambs as a function of the inclusion of spineless cactus a substitute for Tifton-85 hay.

Variable	Spineless cactus inclusion (% dry matter)				CV (%)	R^2
	0.0	6.5	16.63	35.10		
Final live weight (kg)[1]	21.20	27.73	30.80	35.83	9.99	90.84
Live weight at slaughter (kg)[2]	19.68	26.03	28.38	32.40	9.94	87.09
Empty body weight (kg)[3]	13.39	19.07	22.56	27.22	10.89	92.35
Gastrointestinal content (kg)[4]	6.29	6.97	5.83	5.18	15.43	71.16
Hot carcass weight (kg)[5]	7.53	11.07	13.40	16.55	12.10	93.45
Cold carcass weight (kg)[6]	7.12	10.61	12.91	15.87	12.25	92.88
Biological yield (%)[7]	56.10	57.98	59.35	60.66	3.81	90.56
Hot carcass yield (%)[8]	38.19	42.45	47.15	50.92	4.02	93.23
Chilling loss (%)[9]	5.32	4.14	3.36	3.91	25.69	38.44
Cold carcass yield (%)[10]	36.17	40.71	45.56	48.93	4.53	91.29

CV: coefficient of variation; [1]Y: 23.34+0.38x; [2]Y: 21.89+0.32x; [3]Y: 15.23+0.37x; [4]Y: 6.67-0.04x; [5]Y: 8.63+0.24x; [6]Y: 8.24+0.23x; [7]Y: 56.75+0.12x; [8]Y: 39.59+0.35x; [9]Y: 4.67-0.03x; [10]Y: 37.77+0.35x.

as spineless cactus was included in the diet. This is explained by the diets having a different volume:concentrate ratio, so the diets also have different rumen retention times. The animals that received spineless cactus in their diet had a lower percentage of neutral detergent fiber and spent less time in the digestive tract, thus increasing carcass yields. The differences can also be explained by the difference in slaughter weights since no specific slaughter weight was established (Table 2).

For loss on cooling, there was a decreasing linear behavior as the substitution of spineless cactus for Tifton hay increased. This behavior was expected since, as the replacement of Tifton hay with spineless cactus increased, the subcutaneous fat thickness increased, with averages of 1.0, 1.3, 1.3, and 1.7 mm for the 0, 6.5, 16.23, and 35.10% spineless cactus treatments, respectively (Table 2).

The weights of the commercial cuts grew linearly as the substitution of Tifton hay for spineless cactus increased, which was to be expected since the weight of the cold carcass followed the same behavior (Table 3). It should also be borne in mind that the LWS was not pre-determined and the lambs were slaughtered with values ranging from 21.20 to 35.83 kg (Table 2), a variation due to the difference in weight gain. The averages obtained in this study for the treatment with the highest level of spineless cactus inclusion (35.10%) were 86% higher for the neck cut, 116.2% higher for the shoulder cut, 136% higher for the rib cut, 154.6% higher for the loin cut, and 100.8% higher for the leg cut compared to the treatment without spineless cactus inclusion. Palette and leg yields decreased linearly as the inclusion of spineless cactus in the diet increased, and it should be noted that, in addition to spineless cactus, the proportion of concentrate in the diet also increased (Table 1). In this study, the averages for the 35.10% spineless cactus inclusion treatment were 5.91% for neck, 18.44% for shoulder, 14.89% for loin, 31.02% for rib, and 29.75% for leg (Table 3).

Loin eye area, subcutaneous fat thickness, GR measurement, and carcass compactness index were influenced by the diets ($p \leq 0.01$), showing increasing linear behavior as spineless cactus was included in the diet Table 4.

4 DISCUSSION

Alves et al. (2023) evaluated the carcass characteristics of sheep fed a maize-based diet with giant spineless cactus and Mexican elephant ear and found that HCW and yield, CCW and yield, and weight loss due to cooling had values of 11.64, 11.47, 42.56, 43.93, 11.51, 11.29, 42.06, 43.26, 0.14, and 0.17, respectively. They also observed that the commercial cuts were not influenced by the type of diet, but the breast cut showed a significant difference ($p = 0.0166$) with higher values for the animals that consumed the diet with fodder spineless cactus.

For the parameters hot carcass yield, cold carcass yield, and biological yield, the averages observed were similar to those obtained by Santos et al. (2011), who found the following values: 49.57, 48.19, and 57.58%, respectively. The yields observed are

Table 3. Weights and percentages of commercial cuts of Santa Ines lambs as a function of the inclusion of spineless cactus as a substitute for Tifton-85 hay.

Variable	Spineless cactus inclusion (% dry matter)				CV (%)	R^2
	0.0	6.5	16.63	35.10		
Cutting (kg)						
Neck[1]	0.50	0.78	0.92	0.93	18.00	65.48
Palette[2]	0.68	0.99	1.18	1.47	17.14	93.92
Loin[3]	0.50	0.77	0.91	1.18	17.34	94.33
Ribs[4]	0.97	1.47	1.89	2.47	17.36	96.38
Leg[5]	1.17	1.68	2.01	2.35	15.40	89.77
Yield (%)						
Neck[6]	7.00	7.40	7.10	5.91	12.74	72.23
Palette[7]	18.94	18.73	18.29	18.44	5.91	55.13
Loin[8]	13.97	14.68	14.16	14.89	11.75	46.91
Ribs[9]	27.33	27.60	29.29	31.02	5.80	97.89
Leg[10]	32.76	31.60	31.16	29.75	4.95	95.39

CV: coefficient of variation; [1]Y: 0.63+0.01x; [2]Y: 0.77+0.02x; [3]Y: 0.58+0.02x; [4]Y: 1.10+0.04x; [5]Y: 1.35+0.03x; [6]Y: 7.38-0.03x; [7]Y: 18.80-0.01x; [8]Y: 14.14+0.02x; [9]Y: 27.20+0.11x; [10]Y: 32.47-0.08x.

Table 4. Weights and percentages of commercial cuts of Santa Ines lambs as a function of the inclusion of spineless cactus as a substitute for Tifton-85 hay.

Variable	Spineless cactus inclusion (% dry matter)				CV (%)	R^2
	0.0	6.5	16.63	35.10		
Loin eye area (cm^2)[1]	9.77	11.08	14.06	14.80	17.15	85.60
SFT (mm)[2]	1.0	1.3	1.3	1.7	34.46	91.00
Grid rule (mm)[3]	1.7	3.0	4.0	5.2	28.87	94.02
CCI (kg/cm)[4]	0.15	0.20	0.25	0.28	11.36	88.89

CCI: carcass compactness index; SFT: subcutaneous fat thickness; CV: coefficient of variation; [1]Y: 10.32+0.15x; [2]Y: 1.06+0.01x; [3]Y: 2.10+0.09x; [4]Y: 0.17+0.003x.

within the range (40–50%) described by Silva Sobrinho (2001) for specialized breed sheep for meat production.

The effects on the carcass and meat quality of lambs fed finishing diets containing spineless cactus as a substitute for other roughage, such as sugar cane (Oliveira et al., 2017), wheat bran (Abreu Filho et al., 2015; Félix et al., 2016), and Tifton hay (Oliveira et al., 2021), concluding that forage palm can replace up to 49.5% of sugar cane and up to 58.7% of wheat bran without harming carcass and meat quality. Tifton hay associated with spineless cactus provides more significant gains in body weight, cold carcass musculature, and organ weight when compared to those for animals fed maize silage as their sole roughage. However, it is necessary to determine which level of spineless cactus is best as a complement to Tifton hay diets (Lima et al., 2019).

Hot carcass yield and cold carcass yield averaged 46.84 and 45%. These yields can be considered satisfactory and consistent with the carcass yields observed by Pinto et al. (2011) in diets with fodder palm as a substitute for maize (0, 25, 50, 75, and 100%) for Santa Inês sheep slaughtered at 33 kg.

The cut with the highest percentage in relation to the weight of the half-carcass was the leg, at 32.76%. This is an important result, as this commercial cut is the most appreciated by consumers and is also important for muscle reconstitution in the carcass, as it has high correlation rates in terms of its proportions of muscle, bone, and fat in relation to the whole carcass (Cezar & Sousa, 2007).

Considering only the leg and shoulder, the yield was around 49.44%, a similar figure to that found by Oliveira et al. (2021) of 48.75% when studying the carcass characteristics of SRD sheep-fed diets containing forage palm (*Opuntia stricta* Haw) as substitute for Tifton hay, as well as values close to the 51.23% found by Pinto et al. (2011) in a study of Santa Inês lambs-fed diets containing spineless cactus of the Gigante variety as a substitute for maize in the diet.

The loin eye area grew linearly as palm meal levels increased, in line with carcass yield, which had a linear growth effect, since LEA is an indicator of muscularity and, consequently, also of external length, which certainly interfered with loin size. As animals grow, changes in their body measurements become more evident, and those suitable for beef tend to develop more muscle in the posterior (Araújo Filho et al., 2007). At 13.31 cm^2, the loin eye area observed in this study is within the range reported by some authors (Cartaxo et al., 2014), who found values between 5.40 and 14.50 cm^2.

5 CONCLUSIONS

Diets including up to 35.10% forage palm provided higher HCWs, CCWs, cold carcass yields, hot and biological carcass weights, and lower chilling losses. The weights of the commercial cuts also increased with the inclusion of spineless cacti.

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