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Performance and carcass characteristics of Santa Inês lambs fed different protein sources

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ABSTRACT. The objective of this study was to evaluate the productive performance and carcass characteristics of confined Santa Inês sheep, fed different diets, in a Semiarid environment. Twenty whole sheep with 5 ± 0.5 months of age and 27 ± 2.0 kg were used, receiving two different diets for 72 experimental days, one composed of defatted soybean meal and the other of protein-enriched cactus meal. They were evaluated for different diets, consumption, production, carcass characteristics, morphometric measures and edible components. The experimental design was in randomized blocks with two treatments and 10 replications. Performance data and carcass characteristics were evaluated by analysis of variance and means compared by t test at 5% probability level using Statistical Analysis System [SAS]® (1999). Thus, the use of emulsified palm forage protein in the feeding of Santa Inês male lambs proved to be an excellent protein source when compared to the use of defatted soybean meal, since the results of performance and carcass characteristics were similar, being the use of this alternative source advised as it presents the best benefit-cost ratio.

Keywords: cactus; weight gain; xerophyte.

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Introduction

In national livestock, sheep farming represents a significant part of meat production, especially in the South and Northeast regions (Geron et al., 2012; Queiroz et al., 2015), with sheep meat being among the four most consumed in the world (Food and Agriculture Organization of the United Nations [FAO], 2019). The most used breeds are the hairless ones, with emphasis on the Santa Inês breed, which is adaptable to the country's tropical climate conditions, high growth rate and high reproductive capacity (Sena, Borges, Rocha, Castro, & Sarmento, 2021).

In the semiarid region, sheep farming is an activity of fundamental social and economic importance, being responsible for providing food of high biological value and bringing income to the population (Lira et al., 2017)., However, it is a region characterized by short periods of rain and long periods of drought that directly reflects on the supply of food and the nutritional value of forages (Silva, Pereira Filho, Bandeira, & Cordão, 2016a; Oliveira, Ferreira, Freitas, Urbano, & Silva, 2017), in addition to the fact that the herds in this region still present animals without a defined racial pattern that have low productive rates throughout the year. Thus, due to hereditary, nutritional factors and the environment in which the animal is inserted, the supply of meat to the market becomes irregular and the carcasses are of low quality, making it difficult to standardize and value them (Esteves et al., 2018; Silva, Lopes Neto, Costa, Furtado, Miranda, 2018).

In order to avoid some climatological factors and minimize the productive impact of forage shortage, the alternative is to confine the animals, providing food in a homogeneous way, avoiding weight gain with high oscillation and allowing the animal to more satisfactorily express its productive potential (Oliveira et al., 2017). Nevertheless, this rearing system involves the use of commercial concentrates for animal supplementation such as soybean meal, which increases production costs. In this perspective, food alternatives that do not affect animal growth, carcass yield and meat quality, and that can be incorporated into animal feed, making the activity viable, are sought (Pellegrin et al., 2018).

Research carried out using agroindustrial residues in the feeding of small ruminants showed excellent results in animal performance and carcass characteristics, such as soy residue (Grandis et al., 2016), broken rice and brewery malt (Carvalho et al., 2016), guava by-products (Silva et al., 2016b), mazoferm (Oliveira et al., 2017) and orange bagasse (Rego et al., 2019).

The forage cactus is a viable alternative for the region as it is a xerophyte, being a natural source of water and minerals for the animals and considered a forage resource for the subsistence of northeastern cattle raising, with high productive potential in a low rainfall regime (Lima, Lima, Castro, Dias, & Dias, 2017; Souza et al., 2018; Lima et al., 2019). Its use in ruminant diets, however, must be associated with fiber and protein sources, since forage has a low concentration of these components and high moisture content retained in the mucilage, which may cause a laxative effect on animals (Monteiro et al., 2014; Felix et al., 2016; Marques, Gomes, Mourthé, Braz, & Pires Neto, 2017; Oliveira et al., 2017; Alves et al., 2017; Oliveira et al., 2018). Thus, the use of forage cactus with protein enrichment can be an alternative for animal feed. Therefore, the objective of the research was to evaluate the productive performance and carcass characteristics of confined Santa Inês sheep, fed different diets in a Semiarid environment.

Material and method

The procedures performed were approved by the Ethics Committee on the Use of Animals in Research (CEUA), from the Federal University of Campina Grande, Paraíba, Brazil, Protocol nº. 09/2019. The experiment was developed at the Experimental Station of the Federal University of Paraíba - UFPB, in the city of São João do Cariri-PB, located in the Brazilian semiarid region, whose coordinates are: South latitude 07°23'27'' and West longitude 36°31'58'', with an altitude of 445 m, with the climatic classification Bsh (hot semi-arid), according to the Koppen classification (Francisco, Medeiros, Santos, & Matos, 2015).

Twenty Santa Inês whole sheep were used, with an average of 5 ± 0.5 months of age and an average weight of 27 ± 2.0 kg, confined in individual pens, with an area of 3.75 m^2 each, provided with a feeder and drinking fountains, they were vaccinated and previously dewormed, as well as vaccinated and weighed weekly to monitor weight gain.

The treatments were constituted according to the protein sources in the feed: in the first diet, defatted soybean meal (DSM) and in the second, forage palm meal with protein enrichment (FPE), through the biotechnological process of the company Tortuga. The diets were formulated according to the National Research Council [NRC] (2007), to meet nutritional requirements and provide weight gain of 150 g day^{-1}, with 2.6 Mcal of energy kg^{-1} and 12.5% crude protein (Table 1).

Table 1. Percent composition of ingredients and Chemical composition of diets (based on DM) of Santa Inês lambs finished in feedlot.

Percent Composition	Diets kg in Natural Matter (%)	
	DSM	FPE
Maize	38.51	33.14
Mineral Supplement *	1.81	1.56
Limestone	0.45	0.39
Coast-Cross Hay	39.06	33.62
Soybean meal	20.17	-
FPE	-	31.31
Total	100	100
Chemical composition (% Dry Matter)		
Dry Matter	95.24	96.79
Crude Protein	12.92	12.55
Neutral Detergent Fiber	57.02	55.92
Acid Detergent Fiber	25.67	27.07
Organic matter	93.87	93.56
Ashe	6.12	6.43

*Mineral Supplement (nutrient / kg supplement): calcium 120 g; phosphorus 65 g; magnesium 3 g; sodium 175.50 g; chlorine 270 g; zinc 4680 mg; manganese 4400 mg; cobalt 65 g; iodine 60 mg; fluorine 650 mg; selenium 45 mg.

For the preparation of the protein emulsion, a laboratory-scale bioreactor was used, which consisted of a cylindrical drum, built in stainless steel, 58.5 cm in diameter and 89 cm high, with 200 L of volume, equipped with internal swivel blades. This equipment mixed 60 liters of water, 10 kg of palm bran and the one composed of urea, phosphorus and sulfur, in addition to the yeast Saccharomyces cerevisiae, previously selected by the company Tortuga, and this material was constantly stirred for a period of 24h, in the process of aerobic fermentation, which was later served to the animals.

The experimental period was 72 days, with 15 days for adaptation of the animals to the facilities and diets, with the feed offer being adjusted daily, allowing 15% of leftovers. The experimental diets were analyzed at the Animal Nutrition Laboratory of the UFPB, for bromatological determination.

The weight gain in the experimental period was obtained by the difference in the weight of the animal prior to slaughter and the value recorded at the beginning of the experiment, with the feed conversion obtained from the total dry matter consumption of each animal feed, divided by the total weight gain of the confinement period.

After the experimental period, the animals were subjected to a solid and water fast for 16 hours, being weighed before and after it, thus obtaining live weight (LW) and live weight at slaughter (LWS). The animals were stunned, followed by bleeding and the consequent collection of blood and, after skinning and evisceration, the digestive tract was emptied and weighed, to obtain the weight of the empty body and the biological performance.

Immediately after slaughter, the weight of the hot carcass was recorded, obtaining its yield. Subsequently, blood, viscera, organs, skin and attachments were weighed. The carcasses remained refrigerated in a cold chamber at 4°C for 24h, hanging by the tarsus-metatarsal joint, on appropriate hooks with a 15 cm spacing from one to the other.

The experimental design was in randomized blocks with two treatments and 10 replications. Performance data and carcass characteristics were evaluated by analysis of variance (ANOVA) and means were compared by t-test at the level of 5% probability using the GLM (General Linear Model) procedure of SAS® (1999).

Results and discussion

There was a higher consumption of total dry matter in the FPE diet (kg animal^{-1} day^{-1} and %DM) ($p < 0.05$), even though it has a high moisture content, a fact that can cause a reduction in consumption by animals (Pereira Neto et al., 2016), and this higher consumption can be justified by the palatability of the ingredients, high digestibility and not giving animals the opportunity to select diet ingredients (Table 2).

Table 2. Average total dry matter consumption (TDMC), dry matter by percentage of live weight (DMSC), concentrate (CC), forage palm protein emulsion (FPEC), FPE dry matter (DMFPEC), crude protein (CPC), neutral detergent fiber (NDFC) and neutral detergent fiber by percentage of live weight (NDFCLW) of sheep.

Variable (kg)	Protein Source		CV (%)
	DSM	FPE	
Average total dry matter consumption	1.304 b	1.656 a	15.43
Dry matter by percentage of live weight	4.26 b	5.30 a	11.14
Concentrate	1.245 a	1.273 a	17.62
Forage palm protein emulsion	-	0.4281	-
FPE dry matter	-	0.44	-
Crude protein	0.20 b	0.24 a	14.16
Neutral detergent fiber	0.68 a	0.73 a	16.32
Neutral detergent fiber by percentage of live weight	2.26 a	2.34 a	12.09

Averages followed by the same letter in the lines do not differ significantly by the F test at 5% significance

Lower values for dry matter consumption in Santa Inês sheep consuming diets containing corn by-products (mazoferm) were reported by Oliveira et al. (2017), which can be justified by the fact that palm forage has high palatability, providing greater acceptance of the animals when compared to mazoferm. Rego et al. (2019) cite consumption of dry matter lower than that obtained for the FPE diet for Texel sheep fed diets containing orange pomace, which can be justified due to the bitter taste of the limonine present in the orange peels, which result in decreased intake by the animals.

For the variables concentrate consumption (CC), consumption of neutral detergent fiber per kg animal^{-1} day^{-1} (NDFC) and percentage of live weight (NDFCLW), no significant differences were observed between diets ($p > 0.05$), however, a higher consumption of crude protein (CPC) was observed in the diet with FPE ($p < 0.05$) in relation to the consumption of the traditional diet.

The similarities observed for the variables consumption of concentrate, fiber in neutral detergent per kg animal^{-1} day^{-1} and percentage of live weight, can be attributed to the selectivity of the animals in the diet with only soy, which was not possible in the FPE diet, since it formed a more uniform paste.

The higher consumption of CP in the diet with FPE compared to the traditional one can be justified by the higher level of concentrate in the FPE diet combined with greater palatability of the palm, providing high levels of intake. The observed values were higher than those obtained by Oliveira et al. (2017), who evaluated Santa Inês sheep fed mazoferm, observed a decline in the consumption of crude protein with the increase in substitution of the by-product, but no influence on the carcass characteristics was observed. For the NDF consumption variable, no significant difference was observed between diets.

For the variables total weight gain, daily weight gain and feed conversion, no significant differences were observed (Table 3), but the daily weight gains obtained were higher than those recommended by the NRC (2007), of 0.15 kg day^{-1}, demonstrating that the feed provided enough nutrients to meet the needs of the animals.

Table 3. Production of animals receiving diets with defatted soybean meal (DSM) and protein emulsion of forage palm (FPE).

	Protein Source		
	DSM	FPE	CV (%)
Total weight gain (kg)	7.34 a	7.87 a	21.26
Daily weight gain (kg day^{-1})	0.17 a	0.18 a	21.26
Food conversion	7.45 a	8.86 a	26.35

Averages followed by the same letter in the lines do not differ significantly by the F test at 5% significance

High values of weight gain in sheep consuming diets containing alternative foods have been reported in research such as rice chirera diets and brewery malt powder (Carvalho et al., 2016), by-products of guava (Silva et al., 2016b), maize grain (Ferreira et al., 2016), ryegrass and legumes (Pellegrin et al., 2018), and orange pomace (Rego et al., 2019), which attribute such results to the high nutritional value of the diets used and the good acceptance by the animals.

The similarity in feed conversion between diets is related to the better use of nutrients contained in the feed, due to the reduction in the rate of passage of food through the gastrointestinal tract, reinforcing the technical viability of replacing the DSM with FPE. Good feed conversion of sheep consuming peanut pie was reported by Carvalho et al. (2016). Sheep may have good carcass characteristics when consuming alternative foods such as soy cake (Grandis et al., 2016), maize residue (Oliveira et al., 2017), orange pomace (Rego et al., 2019), legumes and concentrate (Pellegrin et al., 2018), and grain maize (Ferreira et al., 2016).

There were no significant differences (p >0.05) between diets for any of the carcass measurements (Table 4). The cold carcass weight, variable used at the time of animals sale, were within the standard recommended for the species (greater than 13.8 kg), varying according to the slaughter and feed weight, presenting values similar to those obtained by Grandis et al. (2016) and Ferreira et al. (2016), mainly due to the similar weight of the animals and the high digestibility of the foods used in these studies.

Table 4. Carcass characteristics of Santa Inês sheep fed defatted soybean meal (DSM) and protein emulsion of forage palm (FPE).

Housing dimensions	Protein Source		CV (%)
	DSM	FPE	
Live weight - (kg)	36.90 a	38.17 a	10.31
Slaughter weight - kg)	35.38 a	36.48 a	10.35
Fasting losses (kg)	0.63 a	0.71 a	20.94
Hot housing weight (kg)	16.65 a	16.89 a	13.09
Cold carcass weight (kg)	16.01 a	16.17 a	12.84
Empty body weight (kg)	30.00 a	31.14 a	11.12
Hot carcass yield (%)	46.99 a	44.13 a	4.75
Cold carcass yield (%)	45.20 a	42.27 a	4.52
Cooling losses (%)	3.81 a	4.19 a	10.93
Commercial income (%)	45.22 a	44.20 a	3.93
Biological yield (%)	55.46 a	54.09 a	3.31

Averages followed by the same letter in the lines do not differ significantly by the F test at 5% significance

For hot carcass weight, a variable obtained right after the slaughter of the animal, values within the recommended for the species (greater than 14.3 kg) were observed, corroborating the values obtained in research developed by Oliveira et al. (2017) and Ferreira et al. (2016).

The weight of the empty body was similar between diets, demonstrating that there was no influence of the type of food on the yield of the variable, which is directly correlated to the body size and bone structure of the animals. The values of empty body weight obtained for the FPE diet were lower than those found by Oliveira et al. (2017) and similar to those reported by Grandis et al. (2016), evaluating carcass characteristics and meat quality of Santa Inês and Ferreira et al. (2016), even using Dorper crossbred sheep, animals more specialized in meat production.

The hot carcass yield obtained was similar to those described by Grandis et al. (2016), evaluating Santa Inês sheep carcass, however, the values obtained by Rego et al. (2019) were higher than those found for the FPE diet. These differences were justified by the breed of animals used, since Texel has greater weight gain and slaughter weight. For cold carcass yield, higher values were observed by Pellegrin et al. (2018), a fact that can be attributed to the greater weight gain of the Ile de France breed and the chemical composition of the diet.

The values of the cold carcass and hot carcass yield are within the standard for Santa Inês male animals finished in confinement, and can be considered positive, as they replace the main protein ingredient used in animal feed, defatted soybean meal with emulsion palm protein, no losses were found in carcass yields.

Cooling losses are important due to the ability to reduce bacterial counts because of the reduction of temperature and surface water activity, being higher in carcasses with less subcutaneous fat thickness, which can vary from 3.12 to 4.3% for Santa animals Inês confined and slaughtered with 38 kg of live weight (Grandis et al., 2016), so it is observed that this loss was within the recommended standard. Oliveira et al. (2017) and Grandis et al. (2016) cite values of loss due to cooling within this standard.

The variables commercial and biological income, serve as a quality reference standard in the slaughterhouses, which can vary between 40 and 60%, depending on the breed, the crossbreeding and the breeding system (Rego et al., 2019). The data of this research are within this variation, corroborating the values obtained by Oliveira et al. (2017).

There were no significant differences (p >0.05) between the morphometric measurements of the different diets. The morphometric measurements of sheep carcasses serve to phenotypically characterize the carcasses of a given breed group to be used in the rearing process. Rego et al. (2019) and Pellegrin et al. (2018) detected inferior results for body length measurements using the Spanish method, facts that can be attributed to different breeds (Texel and Ile de France), feed and the weight of animals at slaughter; while Silva et al. (2016b) cite higher values for the same variable (Table 5).

Table 5. Averages of the external length of Spanish carcasses (ELSC), New Zealand (ELNZC), internal carcass length (ICL), thorax perimeter (TP), thorax depth (TD), thorax width (TW), croup perimeter before (CPB), croup perimeter after (CPA), croup width (CW), leg perimeter (LP), leg length (LL), carcass compactness index (CCI), leg compactness index (LCI) and body compactness index (BCI) of the animals in the two experimental diets.

Morphometric measures	Protein Source		CV (%)
	DSM	FPE	
Averages of the external length of Spanish carcasses (cm)	59.37 a	61.11 a	3.49
New Zealand (cm)	99.37 a	109.83 a	13.45
Internal carcass length (cm)	67.12 a	68.33 a	4.49
Thorax perimeter (cm)	74.37 a	74.61 a	5.27
Thorax depth (cm)	26.62 a	27.27 a	5.89
Thorax width (cm)	22.31 a	21.50 a	6.45
Croup perimeter before (cm)	58.18 a	58.22 a	4.85
Croup perimeter after (cm)	57.81 a	57.88 a	4.43
croup width (cm)	15.75 a	16.05 a	5.78
leg perimeter (cm)	31.01 a	30.33 a	4.86
leg length (cm)	41.06 a	41.77 a	4.50
carcass compactness index (kg cm^{-1})	0.23 a	0.23 a	9.47
leg compactness index	0.75 a	0.72 a	4.27
body compactness index (kg cm^{-1})	0.31 a	0.28 a	17.56

Averages followed by the same letter in the lines do not differ significantly by the F test at 5% significance

For internal carcass length, the same authors observed values lower than those obtained in the present study, possibly due to the difference in the feed used. The thoracic perimeter and croup variables were similar between diets, which may vary according to age, weight and breeds used, with lower values for young and less heavy animals, as well as the type of feed provided (Silva et al., 2016b). Leg length, chest width and croup width can vary between breeds (Ferreira et al., 2016; Pellegrin et al., 2018), with no significant difference between diets in this study.

The leg compactness index (LCI), which indicates the storage capacity of meat in the leg, were similar between diets, indicating that the legs had the same tissue storage capacity. Silva et al. (2016b) cite LCI values ranging from 0.54 to 0.58 kg cm^{-1}, lower values than those obtained in the present study, due to the fact that the animals' legs were shorter, providing greater compactness.

For the variable carcass compactness index, which assesses the amount of muscle tissue deposited per unit length, there was no change between diets, showing that the animals have a greater amount of muscle tissue deposited, thus providing greater compactness, corroborating a study developed by Silva et al. (2016b) with Santa Inês sheep.

The edible components of the carcass (Table 6) did not vary between diets, however, they may vary depending on the breed (Pellegrin et al., 2018), type of dietary ingredient (Ferreira et al., 2016), and weight of the animals (Silva et al., 2016b).

Table 6. Average of edible components of the carcass.

	Protein Source		CV (%)
	DSM	FPE	
Blood (kg)	1.28 a	1.24 a	16.66
Liver (kg)	0.60 a	0.59 a	12.98
Lung + Bronchi (kg)	0.35 a	0.36 a	13.49
Trachea + Larynx (kg)	0.113 a	114.44 a	18.73
Esophagus (kg)	0.05 a	0.05 a	19.32
Spleen (kg)	0.078 a	0.082 a	43.84
Heart (kg)	0.150 a	0.155 a	12.99
Diaphragm (kg)	0.093 a	0.094 a	26.27
Empty stomach (kg)	0.90 a	1.03 a	9.21
Empty intestine (kg)	1.16 a	1.24 a	14.10
Mesenteric Fat (kg)	0.38 a	0.42 a	19.85
Omental Fat (kg)	0.53 a	0.63 a	34.24

Averages followed by the same letter in the lines do not differ significantly by the F test at 5% significance

Conclusion

The supply of diets with forage cactus protein emulsion provided good carcass characteristics, not differing from the characteristics obtained with the defatted soybean meal diet, demonstrating that the replacement of soybean meal by emulsion is feasible, providing high palatability and high nutritional value.

Thus, the use of forage cactus protein emulsion in the feeding of Santa Inês male lambs proved to be an excellent source of protein, when compared to the use of defatted soybean meal, since the results of performance and carcass characteristics were similar, and the alternative source should be used, as it has a better cost-benefit ratio.

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