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Animal feed based on forage cactus: use of viscera in traditional dishes. Production of by-products that can result in an economic return

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Abstract

The study aimed to evaluate the yield of components that are not part of the carcass, edible organs, and with a commercial value of sheep finished in feedlot fed with complete ration silage based on forage cactus and different levels of inclusion of cotton cake. Thirty-two crossbred Dorper lambs with Santa Inês hairless sheep were used, with an initial age of 120 days, weighing on average 17 ± 1.5 kg. Consumption of 5% of the live weight of dry matter was established, being weighed and readjusted daily according to the leftovers of 10% to make then the calculations of the consumption of dry matter (DMC). The weight of blood, heart, digestive tract, liver, diaphragm, kidneys, respiratory system, head, paws, tail, bladder, spleen, gallbladder, skin, and total fat did not show any significant difference ($P > 0.05$) as a function of experimental diets. However, the maximum level tested in this study promotes an increase in the yield of edible organs, representing a potential source of income to add to the property's income.

Keywords: buchada; lambs; organs; added value; red offal; white offal.

Practical Application: The inclusion of cotton cake in the diet to replace traditional sources of forage such as silage or hay becomes an interesting alternative from an economic and environmental point of view.

1 Introduction

Sheep rearing is essential for arid and semi-arid regions, as most of this rearing is in the hands of small breeders (Umaraw et al., 2015). Knowing that the diet of these animals is mainly based on forage and that there is an urgent need to reduce the areas destined for pastures, it is necessary to test the use of diets that have a lower forage share to the detriment of the application of ingredients capable of maintaining low-cost health rumen and less use of arable land (Wirsenius et al., 2010; Swain et al., 2018). Cotton cake has a high fiber content, making it attractive as an alternative roughage food for ruminants (Negrão et al., 2019). Therefore, its inclusion in the diet as a replacement for traditional roughage sources such as silage or hay becomes an interesting alternative from an economic and environmental point of view.

Knowing that the diet of these animals is mainly based on forage and that there is an urgent need to reduce the areas destined for pastures, it is necessary to test the use of diets that have a lower participation of forage to the detriment of the application of ingredients capable of maintaining health. rumen at low cost and less use of arable areas (Wirsenius et al., 2010; Swain et al., 2018). The use of cotton cake for this purpose appears as a promising proposal, since it is a residue from the cotton industry that has a nutritional function of fibrous protein concentrate, given its high percentage of NDF (49.8%) and PB 35.7% (Dias et al., 2019). In addition, as it is an industrial by-product, the price does not fluctuate, making the ingredient attractive for livestock application, preventing such residue from being discarded after processing to extract oil from cottonseed.

The main product explored in sheep farming is meat production; however, the slaughter of these animals produces by-products that can result in environmental pollution, and if they are well used, small farmers can have an economic return (Albuquerque et al., 2019).

The use of by-products such as viscera and blood in the preparation of meat products has been used to reduce environmental pollution and as a great alternative to avoid waste (Dalmás et al., 2011; Cachaldora et al., 2013; Silva et al., 2013, 2014; Albuquerque et al., 2019). The use of by-products for the preparation of meat products is common in several countries, for example, Morcilla de Burgos in Spain (Santos et al., 2003), Cavourmas in Greece (Arvanitoyannis et al., 2000), Morcela de Rice, Chorizo and Beloura in Portugal (Todorov et al., 2010; Pereira et al., 2015), Krvavica in Slovenia (Gašperlin et al., 2014) and Buchada in Brazil (Queiroz et al., 2013; Albuquerque et al., 2019). These by-products are responsible for adding value to meat production and reducing the environmental impact caused by its limited disposal (Toldrá et al., 2012).

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Chopped viscera, blood, and organs (heart, lungs, liver, intestine, and stomach) (Queiroz et al., 2013; Brasil et al., 2014; Albuquerque et al., 2019) are used in the manufacture of a traditional meat product. Brazil as, the buchada, the sarapatel and the "panelada" (Medeiros et al., 2008). Edible components not belonging to the carcass, whose yield may exceed 20% concerning live weight and a budget equivalent to 50% of the total obtained with the carcass.

Some of the viscera used for human consumption have nutritional values similar to those of meat, especially red viscera, constituting, therefore, an essential source of animal protein (Maysonnave et al., 2020). The study aimed to evaluate the yield of components that are not part of the carcass, edible organs, with the commercial value of sheep finished in feedlot fed with complete ration silage based on forage cactus and different levels of inclusion of cotton cake.

2 Material and methods

2.1 Experiment site and ethics committee

The project was sent to the Ethics Committee on Animal Use of the Federal University of Paraíba under protocol No. 5158181018.

The experiment was conducted at the Experimental Station Beijamim Maranhão, of the Paraibana Company for Research, Rural Extension and Land Regularization (EMPAER-PB), located in the Campo de Santana municipality, in the Mesoregion of Agreste Paraibano, Microregion of Eastern Curimataú, 180 km from João Pessoa (06° 29' 18" S, 35° 38' 14" W.Gr.), at 168 m altitude, temperature between 22 and 26 °C and relative humidity of 70%.

2.2 Animal

Thirty-two crossbred Dorper lambs with Santa Inês hairless sheep were used, with an initial age of 120 days, weighing an average of 17 ± 1.5 kg. The animals were housed in individual pens provided with individual food and drinkers, vaccinated, and dewormed. The adaptation period was 14 days, and the lambs were weighed every 14 days, with a total duration of 60 experimental days.

2.3 Diet

The ingredients used were Miúda forage cactus (Nopalea cochenillifera), buffelgrass, ground hay (Cenchrus ciliares L.), corn, cotton cake, and soybean meal ensiled in the form of the total ration. Diets were formulated according to the National Research Council (2007) recommendations for 200 g/animal/day (Table 1).

The onsumption of 5% of the live weight of dry matter was established, being weighed and readjusted daily according to the leftovers of 10% to make then the calculations of the consumption of dry matter (DMC). The feed was supplied twice a day, at 8 am and 4 pm, and water was supplied freely (ad libitum).

The diets were analyzed bromatologically for DM, MM, CP, EB, NDF, NDFcp, ADF The determination of DM, MM,

Table 1. Percentage and nutritional composition of experimental diets based on dry matter.

Ingredients (%)	0%	20%	25%	30%
Forage cactus	34.22	33.92	33.83	33.83
Buffel hay	23.27	6.78	0.00	0.00
Soybean meal	16.15	6.92	2.03	0.00
Corn bran	23.00	30.26	35.86	33.83
Cotton pie	0.00	19.54	25.71	29.77
Urea	0.68	0.00	0.00	0.00
Mineral premix[1]	1.64	1.63	1.62	1.62
Ammonium chloride	0.96	0.95	0.95	0.95
Ammonium sulfate	0.08	0.00	0.00	0.00
Nutritional composition				
Dry matter (g/kg)	296.62	298.50	299.06	299.18
Metabolic energy (Mcal)	2.46	2.60	2.65	2.63
Total digestible nutrients (g/kg)	671.24	734.69	759.62	758.55
Crude protein (g/kg)	156.10	153.66	153.18	153.67
Rumen degradable protein (g/kg)	108.04	106.70	107.90	110.49
Non-degradable protein in the rumen (g/kg)	51.99	36.95	30.39	25.36
Ethereal extract (g/kg)	27.06	46.86	54.79	56.93
Fiber in neutral detergent (g/kg)	362.35	321.75	298.31	311.80
Non-fibrous carbohydrate (g/kg)	440.19	439.38	454.50	434.00

[1]Composition of mineral supplement based on 100 g supply: calcium = 14 g, phosphorus = 11 g, sodium = 7 g, magnesium = 9 g, sulfur = 13.5 g, potassium = 54 g, cobalt = 0.9 mg, copper = 90 mg, iodine = 4.5 mg, manganese = 180 mg, selenium = 0.9 mg, zinc = 270 mg, iron = 450 mg. Vitamins: vitamin A = 20,000 IU, vitamin D = 2,500 IU, vitamin E = 350 IU. Urea = 450 g/kg of nitrogen.

EE and EB followed the methodology described by Association of Official Analytical Chemists (1990); the nitrogen content (CP) was done by the Kjeldahl method (nº 2049, Association of Official Analytical Chemists (1975) The NDF was obtained according to van Soest et al. (1991) and ADF by Robertson & van Soest (1981). Non-fibrous carbohydrate (NFC) were determined according to the methodology of Sniffen et al. (1992), using the formula: NFC=100-(DNFcp+CP+EE+MM) and to estimate the TDN of the ingredients, the formula TDN=(DCCP x DCEE x 2.25 + DCNEC + NDFcp) (National Research Council, 2001).

2.4 Slaughter, carcass, and viscera measurements

After reaching the pre-established score for slaughter (3.5), the animals were subjected to solid fasting for 16 hours and then transported to the Pending Experimental Station (EMPAER-PB) for slaughter. The lambs were weighed, thus obtaining the slaughter weight (SW), slaughtered via cerebral concussion using a captive dart pistol, and then sectioned the jugular and carotid artery for bleeding, collecting the blood for weighing and identification. After bleeding and skinning, the gastrointestinal tract, skin, viscera, head, feet, and genitals were removed. The gastrointestinal tract, bladder, and gallbladder were emptied and washed to obtain empty body weight (EBW).

The hot carcass weight (HCW) was obtained, and after cooling in a cold chamber for 24 hours at 4 °C, the cold carcass weight (CCW) was obtained. Then, the hot carcass (HCW) and cold carcass (CCW) yields were determined by the following formulas: HCW=(HCW/SW) x 100 and CCW=(CCW/SW) x 100. The percentage of total visceral internal fat (IF) was obtained by the sum of renal, inguinal and pelvic fat about the cold carcass weight.

Then, separation and weighing were performed to determine the individual weights of white organs (rumen-reticulum, omasum, abomasum, and intestines) and red (heart, liver, diaphragm, kidneys, respiratory system), blood, and some external body components, such as head, feet, and skin. The loofah weight was calculated by the weight of red organs + white organs + blood. The pan weight was obtained by adding the weight of the sponge with the head and paws (Clementino et al., 2007).

The weight of the edible organs (EO) was obtained by adding the weight of the pan plus the tail, while the weight of the inedible organs (IO) was calculated by the sum of the weights of the empty bladder, empty gallbladder, and spleen, while the weight of the marketable by-products the skin weight and total carcass fat were added. For all weight variables, the yield was calculated about slaughter weight and empty body weight.

The bushing yield was determined based on the bushing weight concerning the animal's live weight at slaughter, using the equation: BY(%) = (weight buchada/SW)x100.

The potting yield was determined by the equation PY(%) = [(WEIGHT buchada + head + paws)SW] x 100.

2.5 Economic analysis

The economic analysis was based on the calculation of the gross margin (GM), in which the gross revenue (GR) was generated from the sale of meat (scenario A) and meat plus non-carcass constituents (scenario B) produced. At the same time, the effective operating cost (EOC) comprised those related to the acquisition of animals, food, labor, deworming, and slaughter costs. Food costs were obtained by multiplying the unit value of each input by the amount consumed in each treatment. Prices were obtained by consulting buyers and suppliers in the region in May 2018.

To the economic analysis was made based on the gross margin (GM), the rate of return (RR), the safety margin (SM), and cost-benefit were determined, adapted from Hoffmann et al. (1987), considering effective operating cost and gross revenue (GR) as total cost and total revenue, where: GM=GR-EOC; RR=GM/EOC; SM=(GM-EOC)/GM*100

2.6 Statistical analysi

The experiment was conducted in a completely randomized design with 4 treatments and 8 replications, according to the statistical model below (Equation 1):

$$Y_{ij} = \mu + t_i + \varepsilon_{ij} \tag{1}$$

Where: Yij = is the observation made in the plot for treatment i in repetition j; μ = overall mean; t_i= represents the effect of treatment i; ε_{ij}= is the experimental error in parcel i, j.

All data were subjected tested for normality and homogeneity using PROC UNIVARIATE. Data were subject to variance analysis, and the variables referring to each treatment (0, 20, 25, and 30% cotton cake) were compared using orthogonal contrasts determined a priori using the GLM. When the effects of contrasts were significant by the Dunnett test, regression analysis (PROC REG) was performed. For all analyses, the SAS program (SAS 9.4, SAS Institute, Cary, NC, USA) was used. For the interpretation of the results, 5% was adopted as the critical probability level for type I error.

3 Results and discussion

The weight of blood, heart, digestive tract, liver, diaphragm, kidneys, respiratory system, head, paws, tail, bladder, spleen, gallbladder, skin, and total fat did not show any significant difference (P > 0.05) as a function of experimental diets (Table 2).

Despite the different feed constitutions and the gradual inclusion of cotton cake up to the 30% level, the diets are isoprotein and isoenergetic can justify the similarity between the organ weights of lambs since the organ growth rates and tissues are affected by nutritional level. Likewise, adult body size and hormonal action also influence visceral development (Costa et al., 2010), but as the animals had similar weights and belonged to the same physiological category (whole males with a similar age), they were not observed changes.

Although not reflecting a significant difference, there was a quadratic trend (P = 0.077) for heart weight, and animals fed 25% cotton cake had lower heart weight. However, this diet had, the highest content of non-fibrous carbohydrates (NFC) (454.50 g/kg),the highest content of non-fibrous carbohydrates (NFC) (454.50 g/kg) and total digestible nutrients (TDN) (759.62 g/kg) numerically. Knowing that the heart and lungs are priority organs in using nutrients and maintaining their integrity even at a low nutritional level (Carvalho et al., 2003), the observed trend is not in line with expectations as described in the literature.

The increase in the size of the liver, kidneys, and spleen may indicate a higher metabolic rate in lambs, as these organs actively participate in the metabolism of nutrients and, therefore, respond to the intake of different energy levels. As the liver is the organ responsible for the uptake of up to 80% of the propionate that passes through the portal system and its conversion to glucose (van Soest, 1994), the increase in concentration levels in the diet and the subsequent increase in dietary energy levels may provoke its development (Moreno et al., 2014).

Studies also report that lambs fed on high protein diets have a higher liver weight, as dietary factors determine their work intensity and boost their growth (Fluharty & McClure, 1997). Despite the findings as mentioned above, in the present study, such developments could not be detected, given the nutritional balance of the tested diets.

Ribeiro et al. (2017) observed an increase in kidney and liver weight of Santa Inês sheep when they replaced the corn silage-based diet with forage cactus associated with Tifton hay. The fact was related to the increased flow of proteins and organic acids generated from the fermentation of abundant palm carbohydrates, inducing hypertrophy in organs that play a central

Table 2. Non-carcass constituents of feedlot finished lambs fed forage cactus silage diets with cotton cake inclusion levels.

Variables	Diets				P value			
	0	20	25	30	MSE	TR	L	Q
Blood (kg)	1.141	1.279	1.183	1.309	0.064	0.230	0.166	0.927
Heart (kg)	0.202	0.173	0.171	0.196	0.015	0.343	0.758	0.077
Digestive system (kg)	2.729	2.664	2.778	2.966	0.175	0.651	0.300	0.474
Liver (kg)	0.543	0.549	0.509	0.540	0.029	0.763	0.711	0.667
Diaphragm (kg)	0.112	0.115	0.105	0.109	0.013	0.955	0.738	0.992
Kidneys (kg)	0.088	0.086	0.086	0.089	0.005	0.965	0.860	0.632
Respiratory system (kg)	0.516	0.542	0.486	0.543	0.047	0.802	0.908	0.746
Head (kg)	1.402	1.357	1.365	1.353	0.043	0.842	0.474	0.700
Feet (kg)	0.739	0.719	0.664	0.759	0.034	0.248	0.968	0.103
Tail (kg)	0.104	0.094	0.097	0.093	0.009	0.831	0.482	0.732
Bladder (kg)	0.011	0.016	0.017	0.015	0.002	0.323	0.256	0.144
Spleen (kg)	0.049	0.048	0.041	0.052	0.005	0.372	0.903	0.181
Gallbladder (kg)	0.019	0.029	0.024	0.030	0.004	0.283	0.166	0.714
Skin (kg)	2.648	2.511	2.707	2.832	0.170	0.610	0.333	0.447
Total internal fats (kg)	0.372	0.430	0.347	0.497	0.140	0.169	0.202	0.359

MSE = mean standard error; TR = treatment.

role in metabolism, supporting the similarity of the data in this study, given the equivalent proportion of forage cactus in diets.

The digestive tract weight was not influenced by the diets (P>0.05). According to van Soest (1994), the growth of the rumen complex can be influenced by several factors, including the diet, especially in terms of NDF content, as diets with higher fiber content have longer retention time in the rumen-reticulum, stimulating muscle development and lamina growth to maintain omasal flow.

Cardoso et al. (2021) found that by increasing the inclusion of forage cactus for sheep, there was an increase in the weight of the viscera. The authors assumed that the increase might have been influenced by the increase in the content of NFC in the diet, inducing, through the production of volatile fatty acids, the growth of ruminal papillae, reticular ridges, and intestinal villi, resulting in more excellent absorption by the gastrointestinal tract and subsequent conversion in edible fabrics.

Carvalho et al. (2017) reported late allometric growth for the rumen, reticulum, and omasum, which may be affected by the aforementioned nutritional factor. However, the authors considered that the abomasum, small intestine, and large intestine are early heterogenic. Based on this premise, the homogeneity of the data obtained is justified since the ruminal sacs with potential for late growth were not stimulated by different proportions of NDF (362.65; 321.75; 298.31 and 311.80 g/ kg) nor of NFC (440.19; 439;38; 454.50 and 434.00 for the levels of 0, 20, 25 and 30% of cotton cake, respectively). Thus, it is possible to reiterate the nutritional and functional efficiency of the replacement of buffel hay by the studied levels of cotton cake associated with forage cactus in the form of complete ration silage.

Alves et al. (2013) found that differences in the head, feet, and skin are related to living weight and to the genetic grouping of sheep, not being influenced by diet or external factors. Thus, as the study animals belonged to the same genetic pattern, the similarity between the variables is justified. Garcia et al. (2014) and Carvalho et al. (2017) described that the lung, heart, kidneys, diaphragm, bladder, spleen, blood, head, and paws develop early, surpassing the muscle and fat growth rate in the early stages of life, a situation that is reversed with the animal's growth, which explains the similarity between the weight of organs observed in the present study, since such organs are matured previously, regardless of the nutritional flow.

There was no influence of treatments on the weight of total internal fat (P = 0.169) or the yield of these fats concerning slaughter weight (P = 0.201). It was observed that up to 1.595% of the animal's weight consisted of internal fat, a value considered low when compared to the results obtained by Jaborek et al. (2017), who fed lambs with alfalfa pallets with energy levels similar to the study (2.66 Mcal vs. 2.46; 2.60; 2.65 and 2.63 Mcal of metabolized energy - ME). The authors observed that 2.94% of the carcass consisted of internal fat, but it should be considered that in addition to pelvic, inguinal, and perirenal fats, the authors accounted for mesenteric and omental fats.

Kozloski (2002) pointed out that the higher concentration of concentrate in the diet of ruminants induces an increase in the concentration of propionic acid in the rumen and consequently decreases the acetate: propionate ratio, resulting in greater availability of energy in the form of glucose since this is the primary neoglycogenic precursor of ruminant metabolism, which favors lipogenesis and consequent deposition of visceral fat.

According to Abouheif et al. (2015) and Zhao et al. (2016), the accumulation of internal fat is considered positive for the animal, as it constitutes an energy reserve that can be used by the body during periods of food restriction, preventing the degradation of muscle protein and weight loss. However, Moreno et al. (2014) state that the deposition of large amounts of visceral fat in sheep is not desired, as there is an increase in energy requirements for maintenance due to the higher metabolic rate of the adipose tissue and, consequently, there is a waste of energy provided by the diet since this fat it is not used for human consumption. However, despite not being intended for human consumption, the use of sheep fat in the chemical, cosmetic, and pet food industry guarantees the use of these scraps as a marketable by-product (Toldrá et al., 2012).

Table 3 shows that the weight of white organs, red organs, and blood, sponge, and pan were not significantly influenced (P > 0.05) by the diets.

The yield of white organs calculated from the weight at slaughter showed a linear effect (P = 0.041) by increasing the proportion of cotton cake in the palm-based silage. Although the weight of white organs and the weight of edible organs were not significantly affected by the experimental rations, numerically, a slight increase in these variables can be observed. Following the opposite trend, the slaughter weight was partially reduced by increasing the inclusion of cotton cake. Although the variables were not significantly altered separately, the correlation between the two implied an increase in income.

Knowing that the weight of white organs is composed of the weight of the digestive tract, the association between white viscera and diet is necessary. Diets with lower energy density have lower digestibility and higher fiber content, represented by the levels of NDF and acid detergent fiber (ADF), causing rumen repletion and providing m,more significant distension in terms of rumen volume.

The weight and yield of red organs and blood did not change due to diet (P > 0.05), an expected result given the absence of significant differences between each variable evaluated separately. Roça et al. (2001) state that the volume of blood collected during slaughter explains the bleeding efficiency, because even under efficient conditions, it is only possible to eliminate between 50 and 60% of the total amount of blood in the animal, as the rest is retained in the muscles (10%) and viscera (20-25%). According to Callegaro et al. (2018), the amount of blood in the animal's body is related to the size of the organs, so the more significant the weight of the organs, the greater the amount of blood, probably to support the higher metabolic rate of the animal.

It was found that the loofah yield and the pancake yield showed an increasing linear effect by increasing the level of cotton cake inclusion from 0 to 30%. Although the higher yield of organs and viscera negatively affects carcass yield, since they are inversely proportional variables, the results showed that, there was no reduction in hot or cold carcass yield (P = 0.889 and P = 0.921, respectively).

When evaluating weight and yield of non-constituent components of the carcass and the yield of bush and pan of lambs fed diets containing 13.8% of CP and decreasing levels of NDT (640, 630, 600, and 520 g/kg), Urbano et al. (2012) found a linear decrease for the weights of the loofah and pan, following the behavior of the weights of the viscera. The highest potting yield

Table 3. Weight and yield of edible organs, inedible organs and marketable products of feedlot finished lambs submitted to diets of forage cactus silage with cotton cake inclusion levels.

Variables	Diets				P value			
	0	20	25	30	MSE	TR	L	Q
Slaughter weight (kg)	30.450	28.525	27.962	30.212	3.771	0.477	0.832	0.129
Empty body weight (kg)	26.584	25.439	24.291	26.946	1.262	0.450	0.992	0.143
Hot carcass yield (%)	51.219	51.784	50.798	51.318	0.886	0.889	0.863	0.980
Cold carcass yield (%)	49.953	50.469	49.634	50.125	0.864	0.921	0.935	0.989
White organs (kg)	2.729	2.664	2.778	2.966	0.494	0.651	0.300	0.474
WO:SW (%)	8.939	9.282	9.907	9.875	1.016	0.184	0.041[1]	0.604
WO:EBW (%)	10.272	10.415	11.389	11.081	1.132	0.175	0.068	0.577
Red organs + blood (kg)	2.602	2.734	2.529	2.786	0.409	0.581	0.596	0.669
ROB:SW (%)	8.489	9.572	9.055	9.259	0.709	0.035	0.121	0.091
ROB:EBW (%)	9.737	10.752	10.427	10.391	0.823	0.118	0.219	0.082
Buchada (kg)	5.331	5.408	5.307	5.752	0.842	0.703	0.393	0.544
Buchada (%)	17.428	18.887	18.963	19.133	1.321	0.055	0.019[2]	0.179
Panelada (kg)	7.000	7.485	7.336	7.865	1.022	0.757	0.529	0.481
Panelada (%)	24.495	26.194	26.226	26.000	1.443	0.058	0.033[3]	0.100
Edible organs (kg)	7.576	7.578	7.433	7.958	1.029	0.766	0.543	0.479
EO:SW (%)	24.833	26.522	26.572	26.508	1.447	0.060	0.035[4]	0.098
EO:EBW (%)	28.521	29.782	30.572	29.750	1.692	0.136	0.106	0.093
Inedible organs (kg)	0.079	0.093	0.081	0.097	0.022	0.313	0.238	0.871
IO:SW (%)	0.262	0.324	0.293	0.328	0.077	0.292	0.176	0.619
IO:EBW (%)	0.300	0.363	0.337	0.369	0.087	0.393	0.203	0.617
Marketable by-products (kg)	3.021	2.941	3.054	3.329	0.547	0.526	0.240	0.367
MB:SW (%)	9.932	10.309	10.922	10.948	1.220	0.289	0.068	0.687
MB:EBW (%)	11.411	11.577	12.548	12.279	1.335	0.282	0.102	0.649

SW = slaughter weight; EBW = empty body weight; HCY = hot carcass yield; CCY = cold carcass yield; WO = white organs; ROB: red organs + blood; EO = edible organs; IO = inedible organs; MB = marketable by-products; MSE = mean standard error; TR = treatment. [1] $y=8.64+0.34x$ (R^2=0.88). [2] $y=17.30+0.52x$ (R^2=0.72). [3] $y=24.59+0,45x$ (R^2=0.50). [4] $y=24.96+0.06x$ (R^2=0.89).

found was 23.01%, a result of the more energetic diet, whereas the yield of boules concerning body weight at slaughter was not affected by the diet, showing values lower than the present research (14.26% vs. 18 .6%).

The higher yields of bushing and pancakes obtained can be based on the linear result observed for the yield of white organs concerning slaughter weight, confirmed by the higher yield of edible organs about slaughter weight (Table 3).

Determining the yield of edible and marketable organs helps determine the optimal slaughter weight and directs studies on the metabolic use of nutrients, especially in lambs. Also, considering that edible, not carcass, is appointed as the fifth quarter of the carcass, as they can add value to sheep production, their determination may represent the exploration of a new product niche, reducing waste and contributing as an extra form of income to the producer.

The weight of edible organs was not affected by the diets (Table 3), but the yield concerning slaughter weight implied an increasing linear effect (P = 0.035), and the yield about empty body weight showed a quadratic trend (P = 0.093).

Among the white viscera are the visceral organs (except the spleen, bladder, and gallbladder) plus the head, legs, blood, and tail. Although there was no unanimity regarding the inclusion of the tail in the left or right half carcass, in the present study, it was removed, evaluated in isolation, and included among the edible, not carcass, as it can be sold and consumed in the form of an sheep tail.

Considering that the cold carcass yield, based on slaughter weight, was 50.04%, the 26.10% yield of edible organs represented the use of a considerable fraction of the slaughter products that would be discarded. In a scenario that includes the yield of marketable by-products, the use rises to 36.63%, considerably reducing the disposal of solid waste and slaughterhouse effluents with putrescible potential.

The yield of non-edible organs and, therefore, destined for disposal was not affected by rations and presented an average of 10.528% about slaughter weight. This variable represents the broke that may be discarded without generating income for the producer, so the smaller its participation in the yield, the more efficient the production system.

Despite not being influenced by the experimental diets (P > 0.05), the weight of marketable by-products such as skin and adipose deposits represents an alternative for billing.

Although the skin cannot be included among the non-carcass edibles when commercialized, it can generate a profit of up to 20% on the total revenue produced by the animal (Silva et al., 2016), but when adequately processed by the leather industry, it can generate an even greater profit. Adipose tissues, on the other hand, have an economic value restricted to the pet animal nutrition market, given the quantitative barrier imposed by the rendering plants.

The market destination of products coming from the fifth quarter, despite having a lower sales value when compared to the price of meat, represents, due to the amount of product generated, a way to recover the investment made by the producer, as reported in Table 4, the carcass weight becomes an index for the sale of products obtained after slaughter, which can be used to generate income in addition to the carcass (Vaz et al., 2015).

Table 4. Economic indicators of lamb production with diets containing forage cactus silage and cotton cake (0, 20, 25 and 30%), considering two production scenarios (A = indicators for carcass sale only and B = indicators for sale of the carcass and non-carcass constituents).

Item		0	20	25	30
		Revenue			
Carcass (kg)		122.200	115.200	111.000	121.700
Edible organs (kg)		59.775	59.790	58.688	62.918
Skin (unit)		8.000	8.000	8.000	8.000
		Costs (R$)			
Purchase of animals (R$)		1,600.000	1,600.000	1,600.000	1,600.000
Food (R$)		63.025	60.183	54.404	56.940
Labor (R$)		92.370	92.370	92.370	92.370
Vermifuge (R$)		6.400	6.400	6.400	6.400
Vaccination (R$)		14.400	14.400	14.400	14.400
Slaughter costs (R$)		30.000	30.000	30.000	30.000
	Scenario	Economic indicators			
Effective operating cost	A	1,791.796	1,788.953	1,783.174	1,785.710
	B*	1,809.714	1,806.843	1,801.005	1,803.567
Gross Income (R$)	A	1,833.000	1,728.000	1,665.000	1,825.500
	B	2,359.200	2,254.320	2,182.504	2,376.844
Gross Margin (R$)	A	41.204	-60.953	-118.174	39.790
	B	549.486	447.477	381.499	573.277
Return Rate (R$)	A	0.023	-0.034	-0.066	0.022
	B	0.304	0.248	0.212	0.318
Safety margin (%)	A	2.248	-3.527	-7.098	2.180
	B	23.291	19.850	17.480	24.119

*1% with non-carcass constituents processing cost; R$ 1.00 = U$$ 3.578.

The value of the effective operating cost (COE), which shows how much resource is being diverted to cover expenses, had a higher value for the situation in which non-carcass constituents are sold with the carcass since costs related to the processing of viscera are added.

Gross income was 30% higher in scenario B compared to scenario A for all tested diets, as well as the gross margin result was positive for scenario B. However, in scenario A the revenues are not higher than the operating cost-adequate when using diets containing 20 and 25% cotton cake, allowing us to conclude that the activity is not remunerating itself and probably not survive

These gross margin results were also reflected in the rate of return. For each real (R$ 1.00) applied to scenario A, R$ 0.023 and R$ 0.022 in profit were achieved by using, respectively, diets with 0 and 30% cotton cake, and R$ was lost. 0.034 and R$ 0.066 when using diets containing 20 and 25% cotton cake. Likewise, by investing one real (R$ 1.00) in scenario B, it was possible to obtain a return of R$ 0.304; R$0.248; R$0.212, and R$ 0.318 for the diets of 0, 20, 25, and 30% cotton cake, respectively.

As for the safety margin, which represents how much sales can fall without the company incurring losses, it is observed that it was higher for scenario B. This scenario means that the market price of the carcass and non-carcass components may suffer devaluation between 24.119% and 17.48%, that the production system continue to achieve profit.

The economic indicators evaluated show the greater economic viability of sheep production systems that apply diets containing 0 and 30% cotton cake inclusion and commercialize the carcass and non-carcass constituents (edible organs and skin). However, it is possible to observe a better economic performance from the sale of carcasses and non-carcass edibles from animals that received the diet containing 30% cotton cake, confirmed by the superiority of R$ 4.33 in gross margin, R$ 4.69 in the rate of return, and 3.56% of safety margin concerning the diet with 0% cotton cake.

4 Conclusions

Including up to 30% of cotton cake in the silage of complete ratio based on forage cactus does not affect the organ weight of lambs. However, the maximum level tested in this study promotes an increase in the yield of edible organs, representing a potential source of income to add to the property's income.

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