Ciências Agrárias
SEMINA

DOI: 10.5433/1679-0359.2024v45n3p749

Characteristics of carcass and non-carcass components of lambs finished with different levels of waste from soybean pre-cleaning as a fibrous feedstuff

Características de carcaça e dos componentes não carcaça de cordeiros terminados com diferentes níveis de resíduo de pré-limpeza de soja como alimento fibroso

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Highlights

Waste from soybean pre-cleaning (WSPC) can be used without affecting lamb carcass.
WSPC is easy to store and does not spoil easily.
WSPC can be used as a roughage source in the diet of feedlot lambs.

Abstract

The objective of this study was to assess the effect of varying levels of sorghum silage replacement with waste from soybean pre-cleaning (WSPC) on the characteristics of carcass and non-carcass components in feedlot-finished lambs. A total of 32 uncastrated, weaned, Texel x Ile de France crossbreed male lambs, at 60 days of age, were used. The treatments consisted of different levels of WSPC replacing roughage (sorghum silage) at 0, 33.5, 66.5, and 100% on a dry matter (DM) basis. For these replacement levels, the inclusion of WSPC in the ration was 0, 150, 300, and 450 g kg^{-1} DM. A roughage-to-concentrate ratio of 45:55, also on a DM basis, was applied. The roughage component

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Received: Aug. 11, 2023 Approved: May 02, 2024

consisted of sorghum silage and/or WSPC, while the concentrate contained corn grits, soybean meal, and calcitic limestone. The lambs were slaughtered upon reaching a live weight of 35 kg. The study found no significant differences (P>0.05) in carcass traits across the different levels of WSPC replacement. Among non-carcass components, however, the proportions of liver, pancreas, thymus, and kidneys increased linearly (P≤0.05) with increasing WSPC in the diet. Regarding the filling of the gastrointestinal tract, the content of the rumen, reticulum, small intestine, and total gastrointestinal content decreased linearly (P≤0.05) with greater WSPC in the diet. Waste from soybean pre-cleaning can replace sorghum silage as roughage in feedlot lamb diets without affecting the characteristics of carcass and non-carcass components. A replacement level of up to 100% (inclusion of 450 g kg^{-1} DM of the ration) is recommended for diets with a roughage-to-concentrate ratio of 45:55.
Key words: Degree of fatness. Performance. Rumen fill. Sheep.

Resumo

O presente experimento teve por objetivo avaliar o efeito de diferentes níveis de substituição da silagem de sorgo por resíduo de pré-limpeza de soja (RPLS) sobre as características da carcaça e dos componentes não carcaça de cordeiros terminados em confinamento. Foram utilizados 32 cordeiros machos, não castrados, cruza Texel x Ile de France, desmamados com 60 dias de idade. Os tratamentos foram constituídos por diferentes níveis de substituição do alimento volumoso (silagem de sorgo) por RPLS em níveis de 0; 33,5; 66,5 e 100% de substituição, em base de matéria seca (MS). Para estes níveis de substituição, a inclusão de RPLS na ração foi 0, 150, 300 e 450 g kg-1 MS. Utilizou-se uma relação volumoso:concentrado de 45:55, com base na matéria seca. As dietas eram compostas por volumoso a base de silagem de sorgo e/ou RPLS, e o concentrado composto por milho desintegrado, farelo de soja e calcário calcítico. Os cordeiros foram abatidos quando atingiram o peso pré-estabelecido de 35 kg de peso vivo. As características das carcaças avaliadas nesse estudo não foram influenciadas (P>0,05) pelos níveis de substituição de silagem de sorgo por RPLS. Quanto às características dos componentes não carcaça, as proporções de fígado, pâncreas, timo e rins aumentaram linearmente (P≤0,05) com o nível de substituição de silagem de sorgo por RPLS nas dietas. Quando avaliado o enchimento do trato gastrintestinal, os conteúdos do rúmen, do retículo, do intestino delgado e o conteúdo gastrintestinal total apresentaram comportamento linear decrescente (P≤0,05) com o aumento de RPLS na dieta. A utilização de RPLS em substituição a silagem de sorgo como alimento volumoso na dieta de cordeiros confinados não altera as características da carcaça e dos componentes não carcaça dos animais, podendo-se recomendar a substituição até o nível de 100% (inclusão de 450 g kg^{-1} MS da ração), em rações com relação volumoso:concentrado de 45:55.
Palavras-chave: Enchimento ruminal. Estado de engorduramento. Ovinos. Rendimento.

Introduction

The sheep meat industry in Brazil has been experiencing growth due to demand for lamb exceeding supply. Producers are adopting new technologies and methods to boost production and efficiency. However, challenges persist due to inconsistencies and a lack of standardization in the supply chain. To address these issues, producers are increasingly utilizing feedlot systems to achieve carcasses with a better degree of fatness, reduce slaughter ages, and enhance animal health.

In spite of the benefits, feedlot systems can be costly due to high nutritional requirements. Producers aim to reduce costs to optimize profits. In this scenario, one cost-effective strategy is to use waste from agro-industries, which often have suitable nutritional characteristics despite lacking a clear market destination. The soybean complex generates various by-products with diverse compositions, depending on factors like cultivar type, harvesting time methods, product purpose, drying, and grinding processes. Thus, when incorporating waste into animal feed, producers must understand its role in the diet.

Waste from soybean pre-cleaning (WSPC) is a high-fiber material (NDF content of 605.1 g kg^{-1} using a 9-mm sieve), making it a potential roughage replacement for conventional options like sorghum silage. Using WSPC in feedlots can reduce costs associated with conventional roughage, which requires significant machinery, inputs, and labor. Sorghum silage also faces climate-related risks, potentially reducing yield and nutritional quality (Cattelam et al., 2018). In contrast, WSPC has a low moisture content (112.2 g kg^{-1}), allowing for extended storage in warehouses without nutritional loss.

Despite limited research on WSPC, its high fiber content supports its use as a roughage source. This is beneficial for production and cost-effectiveness, as it reduces the need for large pasture areas or extensive sorghum plantations, along with their associated processes. Additionally, WSPC is generally acquired at a low cost (Costa et al., 2021).

Against this backdrop, the aim of this study was to assess carcass and non-carcass characteristics of lambs finished in feedlots that used various levels of WSPC as a roughage feed, replacing sorghum silage either partially or entirely.

Material and Methods

The fieldwork for this study was conducted at the Sheep Farming Laboratory, part of the Department of Animal Science at the Federal University of Santa Maria (UFSM). Chemical analyses were completed at the Ruminant Chemistry and Nutrition Laboratory at UFSM. The project received approval from the UFSM Animal Use Ethics Committee (CEUA), under approval number 9650290419. All animal care and slaughter processes adhered to animal welfare and humane slaughter guidelines.

A total of 32 uncastrated male Texel × Ile de France crossbred weaned feedlot lambs, aged 60 days, were used. The lambs were dewormed, and vaccinated against clostridial infections. They were housed individually in fully covered pens with slatted floors rised approximately 1.0 m above the ground. Each pen, measuring 2 m^2, was equipped with feeders and drinkers.

The experimental design followed a completely randomized structure, with four treatment groups and eight replications per treatment. The treatments consisted of varying levels of roughage (sorghum silage) replacement with waste from soybean pre-cleaning (WSPC) (Table 1), with replacement ratios of 0, 33.5%, 66.5%, and 100% on a dry matter (DM) basis. To these levels, the inclusion of WSPC in the ration was 0, 150, 300, and 450 g kg^{-1} DM (Table 2).

The experimental period was preceded by a 10-day adaptation phase for the animals to acclimate to the facilities, experimental diets, and management protocols. The initial average weight of the lambs at the start of the experimental period was 21.7 ± 1.2 kg, with an average age of 70 days. The slaughter criterion was a live weight of 35 kg. The lambs reached an average weight of 35.7 ± 0.3 kg at the end of the feedlot period, with a confinement duration of 45 ± 12 days. They were weighed at the beginning and end of the experimental phase after a 14-h solid food fast. To better track performance, intermediate weighing events occurred every 14 days.

Table 1
Chemical composition of the ingredients used in the formulation of experimental feeds

Item (g kg^{-1})	Sorghum silage	WSPC	Corn grits	Soybean meal	Calcitic limestone
DM	354.5	887.8	868.6	883.0	-
OM	914.4	907.6	987.2	931.7	-
CP	58.3	96.0	88.7	492.0	-
EE	45.4	28.6	49.2	18.5	-
NDF2	591.6	605.1	141.2	165.4	-
ADF	362.0	416.6	29.7	56.9	-
Cellulose	270.0	302.3	18.1	43.6	-
Hemicellulose	229.6	188.5	111.5	108.5	-
Lignin	92.2	114.3	11.61	13.31	-
TC	890.3	815.2	801.8	402.1	-
NSC	217.8	165.2	713.8	279.1	-
TDN	57.23	68.77	87.24	81.54	-
Ash	85.6	92.4	12.8	68.3	1000.0
Calcium	3.4	4.4	0.2	3.0	340.0
Phosphorus	1.7	1.4	2.1	6.9	0.2

[1]Tabulated value (Valadares et al., 2006), [2] Not corrected for nitrogen or ash.
Dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), total carbohydrates (TC), non-structural carbohydrates (NSC), total digestible nutrients (TDN).

Table 2
Proportion of ingredients and chemical composition of experimental diets

Composition[A]	WSPC[1] (g kg^{-1})[B]			
	0	150	300	450
Proportion of ingredients (g kg^{-1})				
Sorghum silage	450.0	299.3	150.8	0.0
WSPC	0.0	150.8	299.3	450.0
Corn grits	254.5	270.5	285.5	300.7
Soybean meal	283.1	268.7	254.6	240.3
Calcitic limestone	12.4	10.8	9.9	9.0
Chemical composition (g kg^{-1})				
DM	643.0	722.9	801.8	881.9
OM	926.5	927.8	928.5	929.2
CP	188.1	188.1	188.1	188.1
EE	38.2	36.2	34.2	32.1
NDF	349	350.9	352.7	354.5
ADF	186.6	194.5	202.2	210.1
TC	712.6	714.3	716.1	718.0
NSC	363.6	363.4	363.4	363.5
TDN	71.04	73.00	74.87	76.77
Ash	61.1	61.4	61.6	61.8
Calcium	6.6	6.2	6.0	5.8

[A]DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; TC: total carbohydrates; NSC: non-structural carbohydrates; TDN: total digestible nutrients.
[B]WSPC = inclusion of waste from soybean pre-cleaning in the diet.

The experimental diets (Table 2) were isoproteic and formulated according to the Nacional Research Council [NRC] (2007) for a 20 kg, late-maturing lamb with a daily weight gain of 200 g. All diets were provided ad libitum. The roughage comprised sorghum silage and/or WSPC, while the concentrates included corn grits, soybean meal, and calcitic limestone (Table 1). Lambs had unlimited access to a mineral salt mix containing (per kilogram) 145 g of calcium, 65 g of phosphorus, 18 g of sulfur, 7 g of magnesium, 125 g of sodium, 80 ppm of iodine, 1400 ppm of manganese, 20 ppm of selenium, 4000 ppm of zinc, 60 ppm of copper, and 100 ppm of molybdenum. The sorghum silage and WSPC ratio varied depending on the experimental diet to achieve the desired level of WSPC on a DM basis. The WSPC used in the experiment was sourced from Cooperativa CAMNPAL, located at BR-158, km 297, Val de Serra, Júlio de Castilhos, RS, Brazil, consisting of the material retained on a 9-mm sieve. Each kilogram of WSPC contained: 156.6 g stalks, 445.4 g pods, 130.4 g soybean hulls, 32.6 g soybean grains, 129.2 g powder, and 105.8 g weed seeds and others.

Throughout the experiment, the diets were provided twice a day, at 08:00 and 17:00. A 15% surplus was established to ensure adequate feed supply, allowing for unlimited feeding. Samples of orts were collected every three days, stored in labeled plastic bags, and frozen at -20 °C for subsequent laboratory analysis.

For chemical analysis, the samples of ingredients (pre-experimental period) and orts (post-experimental period) were pre-dried in a forced-air oven at 55 °C for approximately 72 h, then ground in a Wiley mill with a 1-mm sieve. Dry matter (DM) content was determined by drying in an oven at 105 °C for 24 h, and ash content by incineration in a muffle furnace at 550 °C for 2 h (Silva & Queiroz, 2002). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were obtained following the methodology described by Senger et al. (2008). Lignin (ADL), cellulose, and hemicellulose were measured according to the methodology by Silva and Queiroz (2002). Total nitrogen (N) content was determined using the Kjeldahl method method 984.13, (American Oil Chemists Society [AOAC], 1995), modified according to Kozloski et al. (2003). To convert nitrogen to crude protein (CP), a conversion factor of 6.25 was used. The ether extract (EE) content was obtained by extraction with petroleum ether at 90 °C for 90 min, using ANKOM's XT15 equipment and following the Am 5-04 method (AOCS, 2005). Total carbohydrate (TC) content was calculated using Sniffen et al. (1992): TC (g kg^{-1}) = 100 - (CP + EE + ash), while non-fibrous carbohydrate (NFC) content was derived from TC - NDF (without correction for ash or nitrogen).

Upon reaching the pre-established slaughter weight, the lambs were subjected to a 14-h solid food fast before being weighed, stunned, and slaughtered by bleeding. During slaughter, all blood was collected, and skin, paws, head, tongue, heart, kidneys, liver, lungs with trachea, spleen, penis, internal fat, and perirenal fat, were removed and weighed separately. Additionally, the rumen, reticulum, omasum, abomasum, small intestine, and large intestine were also weighed individually while full. These digestive compartments were then emptied, thoroughly washed, and re-weighed after draining. The relative weights of these organs were calculated as a percentage of the live weight of the lambs.

Following slaughter, the carcasses were weighed individually and refrigerated for 24 h in a cold room at 1 °C. After this period, the cold carcass weight was recorded, and chilling loss index, hot carcass yield, and cold carcass yield were calculated. The cold carcass was then subjectively assessed for conformation (1 = very poor, 5 = excellent) and fatness score (1 = emaciated, 5 = obese) as per the methodology of Osório and Osório (1998).

To measure the ribeye area, a transverse section was made between the 12th and 13th ribs to expose the *Longissimus thoracis et lumborum muscle.* The outline of the muscle was traced onto tracing paper for later determination on a digitizing tablet (Wireless scroll tablet TB-4200). In this same area, additional subjective evaluations were conducted for texture (1 = very coarse fibers, 5 = very fine fibers), marbling (1 = non-existent, 5 = excessive), and color (1 = light pink, 5 = dark red), also using the Osório and Osório (1998) methodology. A caliper was used to measure fat thickness at this point.

Simultaneous to the measurements taken on the left half of the carcass, the right half was weighed and divided into the following retail cuts: neck, shoulder, ribs, and leg (Osório & Osório, 1998). Each cut was then weighed, and its percentage relative to the cold carcass weight was calculated.

The experimental design followed a completely randomized structure, with eight replications for each of the four treatments. After data collection, analysis of variance and regression analysis were performed. Equations were selected based on their coefficients of determination and the statistical significance of the regression coefficients, with a 5% error probability level, using the t-test. The mathematical model applied was as follows:

$$Y_{ij} = \mu + \alpha_{ij} + \varepsilon_{ij},$$

where Y_{ij} = observation of animal j receiving WSPC inclusion level i; μ = overall mean of observations; α_{ij} = effect of WSPC inclusion level i (i = 1, 2, 3, 4); and εij = random error associated with each observation (j = 1, 2, 3, 4, 5, 6, 7, 8).

Results and Discussion

The measurements taken to evaluate the lamb carcass showed no significant differences based on the level of WSPC replacement (P>0.05, Table 3). From the beginning of the experiment, the animals exhibited homogeneous characteristics in terms of genotype, age, and sex. Furthermore, they were slaughtered at a similar live weight, indicating comparable physiological maturity.

Table 3
Carcass traits of late-maturing lambs receiving different proportions of WSPC as a roughage source

Variable[A]	WSPC ($g\ kg^{-1}$)B				RE	CV	P>F
	0	150	300	450			
LW_{Farm} (kg)	36.14	35.78	35.35	35.55	Ȳ=35.70	2.45	0.1203
SW (kg)	33.64	33.26	32.88	33.12	Ȳ=33.22	2.17	0.0943
HCW (kg)	16.41	16.17	16.19	16.55	Ȳ=16.33	3.77	0.1849
CCW (kg)	15.99	15.72	15.70	16.14	Ȳ=15.90	3.86	0.1402
HCY (%)	48.77	48.62	49.28	49.97	Ȳ=49.16	3.25	0.1183
CCY (%)	47.53	47.26	47.94	48.73	Ȳ=47.87	3.29	0.1138
CL (%)	2.54	2.79	2.71	2.48	Ȳ=2.63	15.88	0.1086
CC (1-5)	2.75	3.00	2.75	2.86	Ȳ=2.84	17.54	0.6853
FS (1-5)	2.66	3.16	2.97	2.93	Ȳ=2.93	15.35	0.0915
REA (cm^2)	15.09	17.35	15.90	17.67	Ȳ=16.50	17.31	0.1916
SFT (mm)	1.69	2.09	2.05	1.88	Ȳ=1.92	35.61	0.2562
Texture (1-5)	3.87	3.44	3.44	3.71	Ȳ=3.62	14.75	0.0608
Marbling (1-5)	2.63	2.75	2.31	2.36	Ȳ=2.51	19.74	0.1329
Color (1-5)	2.88	2.63	3.06	2.71	Ȳ=2.82	23.05	0.8549

A Live weight at farm (LWFarm), slaughter weight (SW), hot carcass weight (HCW), cold carcass weight (CCW), hot carcass yield (HCY), cold carcass yield (CCY), chilling loss (CL), carcass conformation (CC), fatness score (FS), ribeye area (REA), subcutaneous fat thickness (SFT).
BWSPC = inclusion of waste from soybean pre-cleaning in the diet.

Like weight gain, carcass yield is an important factor in evaluating the marketability of lambs. Yield represents the percentage relationship between carcass weight and the live weight of an animal (Pilar et al., 2002). The average hot carcass yield and cold carcass yield were 49.16% and 47.86%, respectively, which align with expected values for diets in feedlot lamb production with a forage-to-concentrate ratio of 45:55. Performance metrics such as average daily gain, feed conversion, conformation, and body condition score were not influenced by the replacement of sorghum silage with WSPC, with average values of 0.292 kg, 3.81 kg DM kg gain^{-1}, 3.10 points, and 3.03 points, respectively. Dry matter intake showed similar results, with diets without and with 450 g kg^{-1} DM of WSPC exhibiting values of 1.030 and 1.063 kg day^{-1}, respectively (Costa et al., 2021). We have found that WSPC can provide similar performance and carcass outcomes, offering flexibility to the production system.

Chilling loss reflects the weight difference after chilling the carcass and is mainly influenced by fat cover and moisture loss (Cunha et al., 2008). In this study, irrespective of the WSPC level, the animals showed consistent subcutaneous fat thickness (averaging 1.92 mm) and carcass fatness score (averaging 2.93 points), indicating uniformity in terms of finishing across all treatments. This result explains the lack of observed differences in chilling loss. Furthermore, it is noteworthy that replacing sorghum silage with WSPC was effective in maintaining an adequate degree of fatness at all levels (Table 3). In a study by Carvalho et al. (2015), where sorghum silage was replaced with soybean hulls, chilling loss was unaffected by the proportion of the test ingredient, averaging 3.24%. The current experiment found an average chilling loss of 2.6%, which may vary depending on various factors, primarily the thickness of the fat layer.

Ribeye area (REA) is a representative measure of the proportion of meat in a carcass. In the present study, the REA was not influenced by the level of replacement of sorghum silage with WSPC (P>0.05), indicating similar muscle development across all treatment groups. The average REA was 16.5 cm², a value consistent with the results observed by Carvalho et al. (2017), who reported 15.96 cm². These results are higher than those found in studies by Bernardes et al. (2018), Pires et al. (2006), and Turino et al. (2007), who described 13.81, 11.22, and 12.27 cm², respectively, despite the similar characteristics of the animals in comparison to those in the present study.

Since all evaluated variables related to carcasses and animal performance showed satisfactory and consistent values regardless of the WSPC level, it is evident that including this ingredient in the diet did not negatively impact the carcass characteristics of the lambs. Notably, the feedlot duration decreased linearly from 63 to 34 days with the inclusion of WSPC, which is significant for efficiency and reducing feedlot costs. Because the lambs had similar slaughter weights and the carcass characteristics were also consistent between treatments, the average weights and proportions of the various retail cuts were not statistically affected (P>0.05) by different levels of sorghum silage replacement with WSPC (Table 4). The measurements from different carcass regions are crucial to the economic analysis of lamb feedlot systems.

According to Moreno et al. (2010), the various cuts that comprise a lamb carcass have distinct economic values, and their relative proportions are important indicators of commercial quality.

Table 4
Weights and percentages of retail cuts from late-maturing lambs receiving different proportions of waste from soybean pre-cleaning (WSPC) as a roughage source

Variable	WSPC (g kg^{-1})^{A}				RE	CV	P>F
	0	150	300	450			
Neck (kg)	0.597	0.678	0.646	0.679	$\bar{y}$=0.65	20.84	0.3399
Shoulder (kg)	1.480	1.484	1.415	1.478	$\bar{y}$=1.46	6.93	0.6127
Ribs (kg)	3.041	3.064	2.904	3.205	$\bar{y}$=3.05	9.55	0.1965
Leg (kg)	2.625	2.556	2.553	2.640	$\bar{y}$=2.59	4.87	0.0871
Neck (%)	7.59	8.72	8.53	8.47	$\bar{y}$=8.33	20.11	0.3254
Shoulder (%)	18.88	19.07	18.63	18.49	$\bar{y}$=18.77	6.85	0.4515
Ribs (%)	38.60	39.33	38.17	39.92	$\bar{y}$=39.01	5.72	0.4811
Leg (%)	33.43	32.87	33.62	32.96	$\bar{y}$=33.22	4.14	0.7906

[A]WSPC = inclusion of waste from soybean pre-cleaning in the diet.

The results of this experiment, indicating 8.33% neck, 18.77% shoulder, 39.01% ribs, and 33.22% leg, are comparable to those observed by Carvalho et al. (2017), who reported 9.05% neck, 18.12% shoulder, 39.46% ribs, and 33.36% leg in feedlot-finished Suffolk lambs on diets with varying levels of wet brewers grains. Similarly, Pires et al. (2006) observed mean values of 9.35% neck, 20.25% shoulder, 37.07% ribs, and 34.00% leg when using different levels of NDF in feedlot lamb diets. These results align with the average values reported by L. G. C. Alves et al. (2015) in a review of 22 articles on sheep carcasses, with averages of 19.32% shoulder and 33.97% leg.

The most commercially valuable part of the carcass is the leg, which is prized for its muscle (meat) content. In the present experiment, the percentage of leg was similar to that in the aforementioned studies, indicating that regardless of the level of substitution tested, this region was extremely satisfactory. Given that intrinsic animal characteristics such as breed composition and sex were identical, feed is the other major factor influencing these values. Despite differences in the chemical composition of the roughage, yields were consistent.

Table 5 provides the results of non-carcass components relative to the live weight of the animals. No statistical difference (P>0.05) was found among the variables for lung + trachea, esophagus, spleen, diaphragm, blood, skin, head, paws, internal fat, testicles, or penis. This uniformity might be due to the animals having the same genotype, age, sex, and similar initial and final weights. Queiroz et al. (2015) suggest that no significant differences occur because various components, such as blood, skin, reproductive system + bladder, kidneys, perirenal fat, empty gastrointestinal tract, gastrointestinal contents, respiratory system, and heart, increase at the same rate as body weight during animal development. In this case, as body weight increases, the weight of components also does. Similar results were noted by Siqueira et al. (2001), who used lambs of the same breed in feedlots with similar NDF levels, and described the following mean values: respiratory system 2.17%, spleen 0.14%, blood 3.92%, skin 11.6%, head 5.72%, and paws 2.27%. These findings are corroborated by Carvalho et al. (2007), who reported lung + trachea at 2.19%, spleen at 0.13%, blood at 3.64%, skin at 10.10%, head at 3.70%, feet at 1.91%, and internal fat at 0.62%.

As the level of WSPC increased, a linear increase (P≤0.05) in the proportions of liver, pancreas, thymus, and kidneys was observed. This trend may be attributed to the enhanced activity of organs involved in metabolizing nutrients ingested by the animals, correlating with their increased nutrient intake (Queiroz et al., 2015). Therefore, an elevation in dietary energy levels was noted with the raise in WSPC inclusion (Table 2), which in turn linearly augmented the TDN intake. This increase likely increased the metabolic activities of the animals, resulting in the enhanced development of primary metabolic organs.

Medeiros et al. (2008) noted similar findings, where higher concentrate levels in sheep diets led to increased metabolizable energy and nutrient content, thereby stimulating liver development. This finding suggests that the size of this organ is likely linked to the dietary concentrate and energy levels. This observation supports the association between the increase in certain organ sizes and the linear rise in TDN within the diet, alongside the elevation in waste levels (Table 2).

Analysis of the mean tongue weights of the animals revealed a linear decrease (P≤0.05) as waste levels increased. This phenomenon may be explained by the larger fiber size in the silage compared to the waste, which might have stimulated the tongue muscle, resulting in increased weights at higher silage levels.

Table 5
Non-carcass components (%), relative to live weight at slaughter, of late-maturing lambs receiving different proportions of waste from soybean pre-cleaning (WSPC) as a roughage source

Variable	WSPC (g kg^{-1})[A]				RE	CV	P>F
	0	150	300	450			
Lung+Trachea	1.36	1.28	1.41	1.38	ȳ=13.60	9.80	0.4007
Esophagus	0.15	0.14	0.14	0.16	ȳ=1.50	18.87	0.0709
Heart	0.43	0.42	0.41	0.42	ȳ=4.20	10.53	0.5169
Liver	1.70	1.94	1.85	1.99	1	11.74	0.0404
Pancreas	0.13	0.13	0.16	0.16	2	23.52	0.0391
Thymus	0.26	0.31	0.34	0.47	3	34.68	0.0018
Kidneys	0.26	0.29	0.28	0.31	4	9.75	0.0099
Spleen	0.15	0.16	0.16	0.18	ȳ=1.60	15.84	0.0580
Diaphragm	0.43	0.43	0.42	0.46	ȳ =4.30	13.00	0.2890
Blood	3.98	3.65	4.17	4.46	ȳ=40.60	16.96	0.1002
Skin	11.37	11.88	11.71	11.46	ȳ=116.10	10.22	0.3755
Head	3.25	3.57	3.33	3.38	ȳ=33.80	18.67	0.5471
Tongue	0.37	0.32	0.29	0.25	5	18.73	0.0006
Paws	2.18	2.27	2.25	2.20	ȳ=22.2	18.20	0.6481
Renal fat	0.30	0.44	0.36	0.41	ȳ=3.80	35.31	0.2757
Heart fat	0.15	0.18	0.18	0.22	ȳ=1.80	49.26	0.1815
Internal fat	0.91	1.10	0.99	1.09	ȳ=10.20	0.36	0.4845
Testicles	0.40	0.31	0.36	0.37	ȳ=3.60	32.31	0.2515
Penis	0.16	0.14	0.17	0.15	ȳ=1.50	25.88	0.7904

[A]WSPC = inclusion of waste from soybean pre-cleaning in the diet.
1- Ŷ=1.7549+0.00050WSPC. R2 = 0.14.
2- Ŷ=0.1455+0.0002WSPC. R2 = 0.14.
3- Ŷ=01362+0.0015WSPC. R2 = 0.29.
4- Ŷ=0.1944+0.0008WSPC. R2 = 0.21.
5- Ŷ=0.3622-0.0002WSPC. R2 = 0.34.

Full-rumen weight, rumen content, and gastrointestinal content showed a linear decline (P≤0.05) as silage was progressively replaced with WSPC (Table 6). This outcome is likely due to the higher passage rate of WSPC relative to sorghum silage, a consequence of its smaller particle size (visible to the naked eye). Similarly, the contents of the small intestine exhibited a linear decrease (P≤0.05), consistent with the observations by Camilo et al. (2012), who reported that ground-hay roughage with reduced particle size could diminish the rumen fill effect by facilitating a quicker passage rate and, thus, a shorter feed residence time in the rumen. Thus, the observed linear decrease (P≤0.0001) in rumen fill and gastrointestinal contents in this experiment can be justified by the smaller particle size of WSPC compared to sorghum silage. Additionally, it is important to note that carcass yield calculations based on empty body weight provide more reliable results than those based on live weight due to the variable nature of gastrointestinal content weight (D. D. Alves et al., 2013).

Table 6

Gastrointestinal tract components (%), relative to live weight at slaughter, of late-maturing lambs receiving different proportions of waste from soybean pre-cleaning (WSPC) as a roughage source

Variable	WSPC (g kg^{-1})[A]				RE	CV	P>F
	0	150	300	450			
Rumen, full	11.25	10.29	9.23	8.52	1	13.11	0.0001
Rumen, empty	1.57	1.56	1.50	1.51	$\bar{y}$=15.3	8.24	0.2274
Reticulum, full	0.47	0.49	0.33	0.42	$\bar{y}$=4.23	47.16	0.3271
Reticulum, empty	0.28	0.28	0.27	0.29	$\bar{y}$=2.8	14.88	0.7520
Omasum, full	0.43	0.34	0.37	0.30	$\bar{y}$=3.6	37.79	0.1334
Omasum, empty	0.20	0.23	0.22	0.21	$\bar{y}$=2.1	23.99	0.1999
Abomasum, full	1.81	1.898	1.99	1.83	$\bar{y}$=18.8	25.31	0.4864
Abomasum, empty	0.61	0.63	0.71	0.63	$\bar{y}$=6.5	13.60	0.1432
Small intestine, full	4.82	4.79	4.84	4.54	$\bar{y}$=47.5	11.65	0.4238
Small intestine, empty	2.73	2.73	2.93	2.96	$\bar{y}$=28.4	14.70	0.1976
Large intestine, full	3.86	3.56	3.98	3.77	$\bar{y}$=37.9	14.04	0.8113
Large intestine, empty	1.30	1.43	1.75	1.61	$\bar{y}$=15.2	30.41	0.0957
Rumen content	9.68	8.73	7.73	7.01	2	15.18	0.0001
Reticulum content	0.20	0.20	0.17	0.18	$\bar{y}$=1.9	92.69	0.7466
Omasum content	0.23	0.11	0.15	0.10	$\bar{y}$=0.15	83.76	0.0772
Abomasum content	1.29	1.27	1.28	1.20	$\bar{y}$=12.6	35.23	0.6388
Small intestine content	2.09	2.06	1.92	1.59	3	22.55	0.0287
Large intestine content	2.57	2.14	2.23	0.94	$\bar{y}$=19.7	26.85	0.2526
Gastrointestinal tract content	15.96	14.51	13.47	12.23	4	11.10	<0.0001

[A]WSPC = inclusion of waste from soybean pre-cleaning in the diet.
1- $\hat{Y}$=11.213-0.0062WSPC. R2 = 0.40.
2- $\hat{Y}$=9.642-0.006WSPC. R2 = 0.40.
3- $\hat{Y}$=2.1597-0.0011WSPC. R2 = 0.15.
4- $\hat{Y}$=15.876-0.0082WSPC. R2 = 0.44.

In this experiment, the gastrointestinal content represented an average of 14.04% of the live weight of the animals. This figure is both similar to and lower than that reported by Carvalho et al. (2017), who, working with animals of a similar breed and dietary fiber level (367 g kg^{-1} DM of NDF), recorded a gastrointestinal content of 17.36%. This relatively low value is favorable for carcass yield, particularly notable at the 100%

WSPC inclusion level, which corresponded to the lowest gastrointestinal content and consequently, an improved yield. Hot and cold carcass yields are critically important from both productive and economic perspectives in a sheep meat production system. One of the primary factors influencing these yields is the gastrointestinal content at the time of slaughter (Carvalho et al., 2017). Variations in this content may arise from several factors, including the duration animals are fasted before slaughter, breed, diet type, sex, slaughter weight and/or age, and body fatness (D. D. Alves et al., 2013).

Conclusions

The inclusion of increasing levels of soybean pre-cleaning waste, replacing sorghum silage as roughage in the diets of feedlot lambs, does not alter carcass characteristics. There is a linear increase in the proportions of liver, pancreas, thymus, and kidneys, attributed to the elevated energy levels in the diet.

It is advisable for producers with access to soybean pre-cleaning waste to utilize it as a roughage feed source, replacing sorghum silage up to a 100% level (450 g kg^{-1} of dry matter), maintaining a roughage-to-concentrate ratio of 45:55, when finishing lambs in feedlots.

Acknowledgments

The experiment was partially financed by the following Brazilian Federal Agency: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Brazil - Finance Code 001.

References

Alves, D. D., Araújo, L. M., Monteiro, H. C. F., Leonel, F. P., Silva, F. V., Simões, D. A., Gonçalves, W. C., & Brant, L. M. S. (2013). Características de carcaça, componentes não-carcaça e morfometria em ovinos submetidos a diferentes estratégias de suplementação. *Semina: Ciências Agrárias, 34*(6), 3093-3104. doi: 10.5433/1679-0359.2013v34n6p3093

Alves, L. G. C., Osório, J. C. S., Osório, M. T. M., Fernandes, A. R. M., Ribeiro, E. L. A., Cunha, C. M., Almeida, H. R., & Fuzikawa, I. H. S. (2015). Avaliação da composição regional e tecidual da carcaça ovina. *PUBVET, 9*(1), 6-19. doi: 10.22256/pubvet.v9n1.6-19

American Oil Chemists Society (2005). *Approved procedure. Rapid determination of oil / fat utilizing high temperature solvent extraction.* AOCS.

Bernardes, G. M. C., Carvalho, S., Venturini, R. S., Teixeira, W. S., Motta, J. H., Borges, L. I., Rosa, J. S., Pesamosca, A. C., Mello, V. L., & Moraes, M. L. (2018). Características da carcaça e composição tecidual da carne cordeiros confinados com o uso de dietas de alto grão. *Semina: Ciências Agrárias, 39*(6), 2635-2644. doi: 10.5433/1679-0359.2018v39n6p2635

Camilo, D. A., Pereira, E. S., Pimentel, P. G., Costa, M. R. G. F., Mizubuti, I. Y., Ribeiro, E. L. A., Campos, A. C. N., Pinto, A. P., & Moreno, G. M. B. (2012). Peso e rendimento dos componentes não-carcaça de ovinos Morada Nova alimentados com diferentes níveis de energia metabolizável. *Semina:*

Ciências Agrárias, 33(6), 2429-2440. doi: 10.5433/1679-0359.2012v33n6p2429

Carvalho, S., Brochier, M. A., Pivato, J., Teixeira, R. C., & Kieling, R. (2007). Ganho de peso, características da carcaça e componentes não-carcaça de cordeiros da raça Texel terminados em diferentes sistemas alimentares. *Ciência Rural, 37*(3), 821-827. doi: 10.1590/S0103-84782007000300034

Carvalho, S., Dias, F. D., Pires, C. C., Wommer, T. P., Venturini, R. S., Frasson, M. F., Pilecco, V. M., Moro, A. B., & Brutti, D. D. (2015). Consumo e desempenho produtivo de cordeiros das raças Texel e Ideal terminados em confinamento com dietas contendo diferentes teores de casca de soja. *Semina: Ciências Agrárias, 36*(3, Suppl. 1), 2131-2140. doi: 10.5433/1679-0359.2015v36n3Supl1p2131

Carvalho, S., Frasson, M. F., Simões, F. S. B., Bernardes, G. M. C., Simões, R. R., Griebler, L., Pellegrin, A. C. R. S., Menegon, A. M., Deponti, L. S., Severo, M. M., & Mello, V. L. (2017). Resíduo úmido de cervejaria na terminação de cordeiros em confinamento e seus efeitos sobre as características da carcaça e dos componentes não carcaça. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 69*(3), 742-750. doi: 10.1590/1678-4162-8573

Cattelam, J., Argenta, F. M., Alves, D. C., Fº., Brondani, I. L., Pacheco, P. S., Pacheco, R. F., Mayer, A. R., Rodrigues, L. da S., Martini, P. M. M., & Klein, J. L. (2018). Características da carcaça e qualidade da carne de novilhos e novilhas alimentados com diferentes dietas de alto grão em confinamento. *Semina: Ciências Agrárias, 39*(2), 667-682. doi: 10.5433/1679-0359.2018v39n2p667

Costa, V. R, Carvalho, S., Gallarreta, B. T., Leal, K. W., Silveira, J. M., Oliveira, M. D. F. A., Taschetto, E. A., Kasper, M. A., & Uliana, D. (2021). Terminação de cordeiros em confinamento com diferentes teores de coproduto de pré-limpeza de soja como fração volumosa. *Semina: Ciências Agrárias, 42*(3, Supl. 1), 1797-1812. doi: 10.5433/1679-0359.2021v42n3Supl1p1797

Cunha, M. G. G., Carvalho, F. F. R., Gonzaga, S., Neto, & Cezar, M. F. (2008). Características quantitativas de carcaça de ovinos Santa Inês confinados alimentados com rações contendo diferentes níveis de caroço de algodão integral. *Revista Brasileira de Zootecnia, 37*(6), 1112-1120. doi: 10.1590/S1516-35982008000600023

Kozloski, G. V., Perottoni, J., Ciocca, M. L. S., Rocha, J. B. T., Raiser, A. G., & Sanchez, L. B. (2003). Potential nutritional assessment of dwarf elephant grass (Pennisetum purpureum Schum. cv. Mott) by chemical composition, digestion and net portal flux of oxygen in cattle. *Animal Feed Science and Technology, 104*(1-4), 29-40. doi: 10.1016/S0377-8401(02)00328-0

Medeiros, G. R., Carvalho, F. F. R., Ferreira, M. A., Alves, K. S., Mattos, C. W., Saraiva, T. A., & Nascimento, J. F. (2008). Efeito dos níveis de concentrado sobre os componentes não-carcaça de ovinos Morada Nova em confinamento. *Revista Brasileira de Zootecnia, 37*(6), 1063-1071. doi: 10.1590/S1516-35982008000 600017

Moreno, G. M. B., Sobrinho, A. G. S., Leão, A. G., Loureiro, C. M. B., & Perez, H. L. (2010). Rendimentos de carcaça, composição tecidual e musculosidade da perna de cordeiros alimentados com silagem de milho ou cana-de-açúcar em dois níveis de concentrado. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 62*(3), 686-695. doi: 10.1590/S0102-09352010000300025

Nacional Research Council (2007). *Nutrient requeirements of small ruminants: sheep, goats, cervids, and new worlds camelids.* Washington National Academy Press.

Osório, J. C. da S., & Osório, M. T. M. (1998). *Produção de carne ovina: técnicas de avaliação "in vivo" e na carcaça* (2a ed.). UFPEL.

Pilar, R. C., Pérez, J. R. O., Santos, C. L., & Pedreira, B. C. (2002). *Considerações sobre produção de cordeiros.* Boletim Agropecuário.

Pires, C. C., Galvani, D. B., Carvalho, S., Cardoso, A. R., & Gasperin, B. G. (2006). Características da carcaça de cordeiros alimentados com dietas contendo diferentes níveis de fibra em detergente neutro. *Revista Brasileira de Zootecnia, 35*(5), 2058-2065. doi: 10.1590/S1516-35982006000700025

Queiroz, L. O., Santos, G. R. A., Macêdo, F. A. F., Mora, N. H. A. P., Torres, M. G., Santana, T. E. Z., & Macêdo, F. G. (2015). Características quantitativas da carcaça de cordeiros Santa Inês, abatidos com diferentes espessuras de gordura subcutânea. *Revista Brasileira de Saúde e Produção Animal, 16*(3), 712-722. doi: 10.1590/S1519-99402015000300021

Senger, C. C. D., Kozloski, G. V., Bonnecarrère Sanchez, L. M., Mesquita, F. R., Alves, T. P., & Castagnino, D. S. (2008). Evaluation of autoclave procedures for fibre analysis in forage and concentrate feedstuffs. *Animal Feed Science and Technology, 146*(1-2), 169-174. doi: 10.1016/j.anifeedsci.2007.12.008

Silva, D. J., & Queiroz, A. C. (2002). *Analise de alimentos: métodos químicos e biológicos* (3a ed.). Universidade Federal de Viçosa.

Siqueira, E. R., Simões, C. D., & Fernandes, S. (2001). Efeito do sexo e do peso ao abate sobre a produção de carne de cordeiro. Morfometria da carcaça, pesos dos cortes, composição tecidual e componentes não constituintes da carcaça. *Revista Brasileira de Zootecnia, 30*(4), 1299-1307. doi: 10.1590/S1516-35982001000500025

Sniffen, C. J., O'Connor, J. D., Van Soest, P. J., Fox, D. G., & Russell, J. B. (1992). A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. *Journal of Animal Science, 70*(11),3562-3577. doi: 10.2527/1992.70113562x

Turino, V. F., Susin, I., Pires, A. V., Mendes, C. Q., Morais, J. B., & Oliveira, R. C., Jr. (2007). Casca de soja na alimentação de cordeiros confinados: desempenho e características da carcaça. *Ciência Animal Brasileira, 8*(3), 495-503. doi: 10.5216/cab.v8i3.1713

Valadares, S. C., Fº., Paulino, P. V. R., & Magalhães, K. A. (2006). *Exigências nutricionais de zebuínos e tabela de composição de alimentos BR - corte.* UFV, DZO.