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Impact of total substitution of corn for soybean hulls in diets for lambs

Milena Patricia Viana Bastos[1], Gleidson Giordano Pinto de Carvalho[2], Aureliano José Vieira Pires[3], Robério Rodrigues da Silva[4], Bruna Mara Aparecida de Carvalho[5], Rita Kelly Couto Brandão[1], Camila Maida de Albuquerque Maranhão[2]

[1] *Universidade Estadual do Sudoeste da Bahia, Programa de Pós-graduação em Zootecnia, Itapetinga, BA, Brasil.*
[2] *Universidade Federal da Bahia, Departamento de Zootecnia, Salvador, BA, Brasil.*
[3] *Universidade Estadual do Sudoeste da Bahia, Departamento de Tecnologia Rural e Animal, Itapetinga, BA, Brasil.*
[4] *Universidade Estadual do Sudoeste da Bahia, Departamento de Ciências Exatas e Naturais, Itapetinga, BA, Brasil.*
[5] *Universidade Federal de São João Del-Rei, Departamento de Química, Biotecnologia e Engenharia de Bioprocessos, Ouro Branco, MG, Brasil.*

ABSTRACT - The experiment was conducted to assess the effect of substituting corn for soybean hulls on the apparent digestibility of nutrients, carcass performance and characteristics, and yield of cuts of 25 non-castrated male Santa Ines lambs with an initial body weight of 20±2 kg, at approximately 6 months of age, sheltered individually in stalls (1.10 × 1.0 m), considering a totally randomized design, fed 600 g/kg of forage and 400 g/kg of concentrate. Soybean hulls replaced corn at 0, 250, 500, 750, and 1,000 g/kg of dry matter. The intake of dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF), NDF corrected for ash and protein (NDFap), total carbohydrates (TC), non-fibrous carbohydrates (NFC) and total digestible nutrients (TDN) in g/day, and the digestibility of NFC increased linearly with the soybean hull replacement. Crude protein intake displayed a quadratic response, whereas the intake of EE in g/day, the apparent digestibility coefficients of DM, OM, CP, EE, NDF, ADF, NDFap and TC, TDN, average daily gain, carcass characteristics, and yield of cuts were not affected by the soybean hull levels. Soybean hull substitution increased the intake of DM and nutrients, making it possible to replace up to 1,000 g/kg of dry matter in the diets for confined sheep, as it does not compromise performance, digestibility, carcass characteristics, or yield of cuts when used in sheep nutrition.

Key Words: average daily gain, intensive system, meat production, ovine

Introduction

Agro-industrial by-products may be an economical alternative to corn grain in ruminant diets, especially when the price of corn is high because of the increased demand from the ethanol industry (Ferreira et al., 2011).

Among the difficulties related to the production of lambs in tropical countries, as reported by Bastos et al. (2014), the low quality of forages and their seasonal nature leads to an irregular production of forage over the course of a year. According to the authors, due to the high cost of concentrate food, agro-industrial by-products are being targeted for studies on animal feeding from both the economic and nutritional perspectives.

By-products from grain processing are considered non-forage fiber sources. These by-products are obtained after the extraction of starches, sugars and oils, and can be used as feed for confined animals or pasture supplement, not only reducing the impact of seasonal forage production but also decreasing expenses on concentrated feeds. Among the most used as ingredients in ruminant feeding, soybean hulls, coffee hulls, sugarcane bagasse, cocoa meal, palm kernel cake, and cassava bagasse are notable.

Soybean hulls are a by-product from the soybean processing industry, where the soybean is de-hulled leaving a highly digestible, fibrous feed (Bittner et al., 2013). Many studies have demonstrated the advantages of using soybean hulls as an energy source for ruminants in replacement of corn, as long as it is supplied together with effective fiber sources to reduce the rate of passage and enable ruminant fermentation (Faulkner et al., 1994; Ipharraguerre et al., 2002; Moore et al., 2002). We hypothesized that soybean hull can replace corn in feedlot lambs without negative effects on feed intake, performance, or carcass characteristics.

The present study was conducted to assess the effect on intake, digestibility, performance and carcass characteristics of different levels of soybean hulls as substitute for corn in diets for Santa Ines lambs.

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Corresponding author: gleidsongiordano@yahoo.com.br

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Material and Methods

The experiment was conducted in Itapetinga, BA, Brazil, in the period between June and October 2009.

Twenty five non-castrated male Santa Ines lambs at an average age of six months and with an initial body weight of 20±2.0 kg were sheltered in individual stalls (1.10 m^2) provided with cement floors, feeders, and drinkers.

In the pre-experiment period the stalls were numbered and the animals were earmarked, dewormed for endoparasites and, after a random draw, distributed throughout treatments consisting of diets with different levels of soybean hulls as substitute for corn in the concentrate (0, 250, 500, 750, and 1,000 g/kg of dry matter), in accordance with a completely randomized experimental design.

The experiment lasted 106 days, of which 14 days were spent adapting the sheep to the facilities, experimental diets and management, and 92 days were used for assessment and data collection. During this period, intake adjustments were made by weighing the feed supplied and the surplus allowing ingestion at will, with a surplus of 100 g/kg of fresh matter. The diets were formulated in accordance with the nutritional recommendations of NRC (2006), aiming at an average daily gain of 200 g, and diets were formulated in an attempt to be isoproteic, with 160 to 187.0 g/kg of crude protein on a dry matter basis (Table 2).

Elephant grass silage was used as forage at a forage: concentrate ratio of 600 g/kg to 400 g/kg. The concentrates were composed of corn, soybean meal, urea, a mineral mixture, and soybean hulls (Table 1).

The diets were supplied twice a day at 06.00 h and 15.00 h in the form of complete feed (silage + concentrate). Water was permanently available to the animals, in plastic buckets.

During the experimental phase, concentrate samples were taken weekly and surplus and silage samples were collected daily, forming composite samples every 21 days per period, per animal and per treatment, which were placed in plastic bags and stored in a freezer (−10 to −5 °C).

At the end of the experiment, the samples were defrosted at room temperature for 4 h. After that, they were pre-dried in a forced air circulation oven at 55 °C for 72 h and processed in a Wiley cutting mill using a 1 mm sieve. The levels of dry matter (DM), crude protein (CP), ether extract (EE), and mineral matter (MM) were estimated according to the recommendations of the Association of Official Agricultural Chemists (AOAC, 1990), as described by Silva and Queiroz (2002), and the levels of neutral detergent fiber (NDF), hemicellulose (HEM) and lignin (H_2SO_4 72%), according to the methodology described by Van Soest et al. (1991). The organic matter (OM) was obtained using the following formula: OM (g/kg DM) = 100 − MM (g/kg DM). Total carbohydrates (TC) were estimated according to Sniffen et al. (1992), as follows: TC = 100 − (g/kg DM CP + g/kg DM EE +g/kg DM MM), whereas the levels of non-fibrous carbohydrates (g/kg DM) in samples of feed, surplus, and feces were assessed using the equation proposed by Hall (2000): NFC = 100 − (CP + EE + MM + NDFap). Total digestible nutrients (TDN) were calculated according to Weiss (1999), but using NDF and NFC corrected for ash and protein, with the following

Table 1 - Chemical composition of the ingredients of experimental diets

	Ingredient			
	Elephant grass silage	Corn	Soybean meal	Soybean hulls
Dry matter[1]	262.5	878.9	897.2	891.9
Organic matter[2]	913.2	982.1	932.6	966.1
Crude protein[2]	58.7	71.1	445.0	88.0
Ether extract[2]	25.0	20.5	16.8	21.3
Mineral matter[2]	86.8	17.9	67.4	33.9
NDF[2]	764.0	139.0	143.0	699.0
Hemicellulose[2]	332.6	102.9	46.5	215.4
Lignin[2]	77.6	17.2	18.0	31.3

NDF - neutral detergent fiber.
[1] g/kg of fresh matter.
[2] g/kg of dry matter.

Table 2 - Ingredients and chemical (g/kg) composition of experimental diets

Ingredient	Level of soybean hulls[3]				
	0	250	500	750	1,000
Corn[1]	208.0	156.0	104.0	52.0	0.00
Soybean meal[1]	171.6	171.2	172.0	172.8	173.2
Soybean hull[1]	0.00	52.0	104.0	156.0	208.0
Urea[1]	24.0	22.0	20.0	18.0	17.0
Mineral mixture[1,4]	30.0	30.0	30.0	30.0	30.0
Elephant grass silage[1]	600.0	600.0	600.0	600.0	600.0
Total	1,000.0	1,000.0	1,000.0	1,000.0	1,000.0
Chemical composition					
Dry matter[2]	508	509	509	513	512
Organic matter[2]	930	925	925	924	923
Crude protein[2]	185	170	160	187	176
Ether extract[2]	28	30	28	29	26
Mineral matter[2]	70	75	75	76	77
Neutral detergent fiber[2]	516	534	536	554	575
Acid detergent fiber[2]	273	273	273	274	273
NDFap[2]	388	391	392	389	386
Total carbohydrates[2]	717	724	737	708	721
NFCap[2]	329	333	345	319	335
TDN[2]	823	792	771	782	784

NDFap - neutral detergent fiber corrected for ash and protein; NFCap - non-fiber carbohydrates corrected for ash and protein; TDN - total digestible nutrients.
[1] g/kg of dry matter.
[2] g/kg fresh matter.
[3] Level of corn replaced with soybean hulls in the concentrate.
[4] Guaranteed level (nutrients/kg): calcium - 170 g; sulfur - 19 g; phosphorus - 85 g; magnesium - 13g; sodium - 113 g; copper - 600 mg; cobalt - 45 mg; chrome - 20 mg; iron - 1,850 mg; maximum fluorine - 850 mg; iodine - 80 mg; manganese - 1,350 mg; selenium - 16 mg; zinc - 4,000 mg.

equation: TDN (g/kg DM) = DCP + DNDFap + DNFCap + 2.25DEE. Voluntary intake of DM and of the other diet components was calculated as the difference between the quantities supplied and surplus. The intakes of DM, OM, CP, EE, NDF, TC, NFC, and TDN were estimated in kg/day and % of body weight in relation to metabolic weight.

Lambs were weighed at the beginning of the experiment and every 21 days before the first meal, after approximately a 16-h period of deprivation of solid foods. At 92 days of the experimental period, the animals were weighed to obtain their average daily gain (ADG), feed conversion (FC), and feed efficiency (FE).

The digestibility assay lasted eight days; three days for adaptation to the collecting bags and five days to collect the feces, which occurred after 81 days had elapsed.

The feces were collected daily at 06.30 h and 15.30 h and weighed for a 10% aliquot sampling of the total excreted by each animal. This sample was conditioned in duly identified plastic bags, sealed, and stored in a freezer (−10 to −5 °C).

The material was subsequently processed at the end of the experimental period in the same manner as feed and leftovers. The material collected was defrosted, homogenized, a composite sample was made per animal, dried in an oven with forced ventilation at 55 ºC for 72 h, and processed in a cutting mill with a 1 mm sieve and stored for later analysis.

The apparent digestibility coefficients (ADC) of nutrients were calculated as described by Coelho da Silva and Leão (1979): ADC = [(Ingested nutrient – Excreted nutrient)/Ingested nutrient]. After 92 days of the performance experiment, the animals were transported to a slaughterhouse in Feira de Santana-BA, for slaughter.

The lambs were weighed after a 16-h period of deprivation of solid foods to obtain their body weight at slaughter (BWS) and were later stunned, followed by bleeding, and sectioning of the jugular veins and carotid arteries. After slaughtering, skinning, evisceration, and removal of the head, feet and testicles, the hot carcass weight (HCW) was obtained by calculating the hot carcass yield (WCY) with the following formula: HCY = HCW/BWS × 100. In sequence, the carcasses were cleaned and taken to the cold chamber where they remained for 24 h at an average temperature of 4 °C, hung by their tarsometatarsal articulation on adequate hooks, approximately 17 cm distant from one another. After this period, the carcasses were weighed to obtain the cold carcass weight (CCW), and the cold or commercial carcass yield (CCY) was calculated using the following formula: CCY = CCW/BWS × 100. After that, the carcass was cut lengthwise, resulting in right and left half-carcasses.

The following assessments were carried out on the cold carcass, according to Osório (1998): Carcass length (cm), measured with a metal tape measure from the anterior edge of the pubic bone to the cranial edge of the first rib; Chest depth (cm), measured with a metal tip compass placed between the dorsum and the sternum, in the shoulder blade area, at maximum distance; Leg length (cm), measured with a compass with its tips placed on the anterior edge of the pubic bone and the medium point of the bones in the tarsum articulation; and Leg width (cm), measured with a metal tip compass placed on the lateral and medial side of the upper leg portion. Subsequently, the following assessments were carried out: fattening status (subjective scale from 1 to 5 with 0.5-point intervals, wherein 1 = excessively thin and 5 = excessively fat) and conformation (subjective scale from 1 to 5 with 0.5-point intervals, wherein 1 = very poor and 5.0 = excellent), according to the methodology described by Osório (1998).

The following were determined between the 12th and 13th ribs of the left carcass, on the surface of the *longissimus dorsi* muscle: loin eye area (cm^2), by tracing the muscle contour on greaseproof paper; texture (subjective scale of 1 to 5 with 0.5-point intervals, wherein 1 = very coarse and 5.0 = very fine); marbling (subjective scale of 1 to 5 with 0.5-point intervals, wherein 1 = inexistent and 5.0 = excessive); and color (subjective scale of 1 to 5 with 0.5-point intervals, wherein 1 = pale pink and 5.0 = dark red).

After the left half carcass assessments were concluded, the carcasses were subdivided into five anatomical regions: neck, loin, rib, leg and shoulder, according to a methodology adapted from Silva Sobrinho (1999). The commercial cuts were weighed separately and then the percentages of each cut were calculated relative to the left half-carcass, as per the recommendations of Cesar and Sousa (2007).

Statistical analyses of the data were carried out with a software program SAEG (Sistema para Análises Estatísticas e Genéticas) by means of analysis of variance and regression, with a 5% significance level.

Results and Discussion

The intake values of DM, OM, NDF, NDFap, TC, NFC, and TDN (g/day), increased linearly (P<0.05) due to the levels of soybean hulls as substitute for corn (Table 3). Intake of DM increased by 0.012 g/day for each percentage unit of soybean hulls added to the feed.

Furthermore, the lower energy density of soybean hulls as compared with corn (NRC, 2007) may have contributed to the increase in DM intake (DMI), since an increase in NDF concentrations in feeds with higher levels of soybean hulls did not cause a reduction in DMI. Therefore, the filling effect did not take place, because one of the factors regulating feed intake is energy density.

According to Mertens (1992), DMI is negatively correlated with NDF concentration, when rumen filling limits ingestion, but positively correlated when energy is the limiting factor. Possibly, the high degradation potential of NDF in soybean hulls was the determining factor that caused this fiber source not to be a physical limitation to DMI.

Dry matter intake expressed as body weight (g/kg BW), and metabolic weight percentage (g/kg $BW^{0.75}$) was not influenced (P>0.05) by an increase in the levels of soybean hulls in the diet (Table 3), with average values of 26.0 and 59.0, respectively. Santos et al. (2008) did not detect an increase in DMI (3.40% LW) from the use of soybean hulls as substitute for corn at levels 0, 25, 50, and 75% in the diets for confined sheep.

Soybean hulls influenced NDF intake, resulting in its linear increase, since there was an increase in DMI, and because the NDF from soybean hulls are more digestible, although their concentration in soybean hulls is higher than in corn. Soybean hulls presented 71.80% DNDF, whereas corn presented 32.33%. This high soybean hull NDF degradation was a preponderant factor for this fiber source not to be a limiting factor for DMI and consequently of fiber, which provided an elevation in NDF intake. This increase is due to the higher level of NDF in soybean hulls as compared with corn. The corn used in the present study had 139.0 g/kg NDF and 699.0 g/kg soluble carbohydrates. It should be stressed that NDF in soybean hulls are presented as small particles with a low amount of lignin. The average EE intake value was 23.3 g/day and there was no influence from soybean hulls, because EE concentration is low and there were no differences in the values with the substitution of corn for soybean hulls.

Crude protein presented a quadratic effect (P<0.05), with a minimum value of 112.28 g at the level of 369.7 g/kg of inclusion of soybean hulls as substitute for corn. The increase in protein intake can be possibly related to the DMI increase raising the intake of fibers to meet the animal demands according to the inclusion of soybean hulls in the diets.

The intake increases detected for NDF, NDFap, TC, and NFC can be attributed to DMI and its higher concentration with the substitution of corn for soybean hulls in the diet. This also happens with TDN intake, which increased linearly (P<0.05) with the inclusion of soybean hulls,

Table 3 - Intake of nutrients by lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
			Intake (g/day)						
Dry matter	644.9	700.1	671.2	713.3	792.5	12.0	0.027[1]	0.441	0.324
Organic matter	614.6	661.7	637.8	676.9	750.3	11.9	0.029[2]	0.426	0.362
Crude protein	143.2	136.5	121.7	156.4	156.3	9.6	0.042	0.013[3]	0.198
Ether extract	21.1	24.9	22.0	23.3	25.2	12.8	0.156[4]	0.171	0.101
Neutral detergent fiber	252.9	280.4	266.8	287.4	330.3	15.9	0.029[5]	0.427	0.332
NDFap	242.7	272.1	257.8	270.9	299.6	12.8	0.045[6]	0.696	0.242
Total carbohydrates	527.2	569.4	551.3	581.4	646.9	12.0	0.028[7]	0.454	0.343
Non-fiber carbohydrates	456.3	479.3	466.7	491.6	548.1	10.2	0.019[8]	0.248	0.354
Total digestible nutrients	530.7	578.3	553.7	604.6	676.4	12.1	0.008[9]	0.339	0.367
			Intake (g/kg BW)						
Dry matter	24.3	26.4	24.6	26.6	27.5	9.6	0.096[10]	0.760	0.438
NDFap	9.1	10.2	9.4	10.1	10.4	10.2	0.137[11]	0.904	0.289
			Intake (g/kg $BW^{0.75}$)						
Dry matter	55.1	59.8	56.2	60.4	63.6	9.4	0.049[12]	0.633	0.374
NDFap	20.7	23.2	21.6	22.9	24.0	10.1	0.078[13]	0.975	0.249

NDFap - neutral detergent fiber corrected for ash and protein; BW - body weight.
SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] $\hat{Y} = 644.006 + 0.0118476X$.
[2] $\hat{Y} = 612.088 + 0.0110141X$.
[3] $\hat{Y} = 142.667 - 0.548019X + 0.00741089 X^2$.
[4] $\hat{Y} = 23.3$.
[5] $\hat{Y} = 251.859 + 0.621005X$.
[6] $\hat{Y} = 246.470 + 0.435885X$.
[7] $\hat{Y} = 525.936 + 0.967114X$.
[8] $\hat{Y} = 450.157 + 0.746337X$.
[9] $\hat{Y} = 526.321 + 0.0122651X$.
[10] $\hat{Y} = 26.0$.
[11] $\hat{Y} = 9.0$.
[12] $\hat{Y} = 59.0$.
[13] $\hat{Y} = 22.5$.

possibly by virtue of a higher ingestion of NFC and other more digestible components, such as protein and NDF.

The levels of soybean hulls as substitute for corn had no influence (P>0.05) on the digestibility of DM, OM, CP, EE, NDF, NDFap, TC, and the level of TDN (Table 4). According to Gentil (2010), although the fiber portion in diets was increased with the inclusion of soybean hulls, it is highly digestible, which probably caused the lack of effect on DM digestibility and other components.

Despite having a small particle size, which favors digestion, soybean hulls also have low levels of lignin, and this is also related to the DM digestibility values in diets where it is included as ingredient. The lack of a significant effect for the observed DM and OM digestibility is in agreement with other studies found in the literature, in which soybean hulls were used as substitute for corn in diets for milking cows, and no effects were observed on the apparent digestibility of DM and OM (Mcgregor and Owen, 1976; Ipharraguerre et al., 2002). According to these authors, this response may be explained by the qualitative characteristics of the fiber and by the quantity and physical form of the soybean hulls, which provide an increase in fiber digestion and at the same time an increase in the rumen passage rate as a compensation process (Ipharraguerre et al., 2003), because digestion is the result of an interaction between digestion rates and permanence at digestion sites (Van Soest, 1994).

An upward linear effect (P<0.05) was observed in NFC digestibility (Table 4) due to increased soybean hulls in the lambs' diets. Since soybean hulls have high levels of NDF, the level of NDF in diets containing soybean hulls can be lower but with high digestibility, which is why it may have contributed to raise digestibility.

The levels of TDN in the experimental diets were not affected by the levels of soybean hulls as substitute for corn. Good-quality soybean hulls, associated with rapid fermentation and rumen digestion, may have contributed to the observed values.

No effect (P>0.05) of the levels of soybean hulls as substitutes for corn was observed on initial weight (IW), final weight (FW), average daily gain (ADG), feed conversion (FC), or feed efficiency (FE) (Table 5).

Similar results were found by Santos (2008), who replaced corn with soybean hulls at 0, 25, 50, and 75%, in diets for confined Santa Ines lambs mixed with 50% forage and did not observe any effects on ADG or FC.

The chief factor allowing soybean hulls to maintain animal performance when offered as substitute for corn in diets with higher proportions of forage is the reduction of the negative associative effect of corn on the fiber digestion (Sarwar et al., 1992).

The efficiency with which the animal transforms feed into weight gain is presented in the form of feed conversion and followed the same response as weight gain, because FC is a function of ADG and DMI.

No significant effect (P>0.05) of the levels of soybean hulls as substitutes for corn were observed on body weight at slaughter (BWS), hot carcass weight (HCW), cold carcass weight (CCW), hot carcass yield (CCY), or cold carcass yield (CCY) (Table 6).

Table 4 - Apparent digestibility ($_D$) of nutrients and total digestible nutrients (TDN) in lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
	g/kg of DM								
Dry matter$_D$	0.703	0.707	0.736	0.726	0.771	0.973	0.087[1]	0.680	0.709
Organic matter$_D$	0.715	0.720	0.750	0.741	0.782	0.866	0.075[2]	0.741	0.738
Crude protein$_D$	0.860	0.860	0.861	0.880	0.893	0.504	0.075[3]	0.741	0.738
Ether extract$_D$	0.668	0.725	0.733	0.673	0.694	1.300	0.401[4]	0.263	0.244
Neutral detergent fiber$_D$	0.599	0.628	0.657	0.642	0.684	1.280	0.115[5]	0.858	0.601
NDFap$_D$	0.755	0.738	0.774	0.746	0.776	0.984	0.601[6]	0.766	0.957
Total carbohydrates$_D$	0.713	0.722	0.753	0.745	0.787	0.919	0.051[7]	0.804	0.717
Non-fiber carbohydrates$_D$	0.807	0.817	0.838	0.841	0.872	0.633	0.011[8]	0.718	0.749
Total digestible nutrients	0.823	0.829	0.823	0.847	0.854	0.617	0.105[9]	0.535	0.898

NDFap - neutral detergent fiber corrected for ash and protein.
SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] $\hat{Y} = 0.729$.
[2] $\hat{Y} = 0.742$.
[3] $\hat{Y} = 0.871$.
[4] $\hat{Y} = 0.699$.
[5] $\hat{Y} = 0.642$.
[6] $\hat{Y} = 0.758$.
[7] $\hat{Y} = 0.744$.
[8] $\hat{Y} = 0.804676 + 0.0604656X$.
[9] $\hat{Y} = 0.835$.

If the initial body weight, weight gain, and body weight at slaughter are similar, similar carcass weights are justifiable. The results obtained for HCW and CCW presented the same response observed for ADG and repeat once more the good quality of the soybean hulls. Cold carcass weight (CCW) is an indicator of the degree of animal status, quality of the cooling process to which the carcass was subjected, and the yield of cuts, all of which are important parameters for both slaughterhouses and consumers.

No difference was observed for variables hot carcass yield (HCY) and cold carcass yield (CCY) in the present study. Their averages as found in this study were 46.4 and 46.2% (Table 6). Similarities in live weight associated with same age probably contributed to the lack of influence on carcass yield, since, according to Cezar and Sousa (2007), among the factors inherent to animals, live weight and age are probably those that influence carcass yield the most.

According to Sañudo and Sierra (1986) and Pérez and Carvalho (2004), lamb carcass yields can vary from 40 to 60% according to breed, crossbreeding, age, gender, weight at slaughter, and livestock system, among other factors. The carcass yield in the present study is thus in accordance with literature.

Variables conformation, fattening status, carcass length, leg length, leg width, chest depth, loin eye area, texture, marbling, and color were not influenced (P>0.05) by the inclusion of soybean hulls as substitute for corn in the diet (Table 7). Conformation is related to genetics and fattening status, and the latter can be influenced by the animal gender, especially as the animal ages (Jacobs et al., 1972; Seideman et al., 1982; Safari et al., 1988).

The lack of a significant effect on carcass length, leg length, leg width, or chest depth can be explained by the animals' young age, similar initial body weight and body weight at slaughter, due to the lack of difference in ADG, which manifested no difference in morphology, but would probably present differences with age (Osório et al., 1995; Oliveira et al., 1998).

The measurement of the loin eye area (LEA) taken in the *longissimus* muscle reflects the carcass meat composition and has shown to be directly related to the total muscles in the carcass; also, it helps to assess the degree of yield of boneless cuts.

The average LEA value was satisfactory at 12.4 cm^2, in accordance with those found in literature for Santa Ines lambs, which vary from 9.6 to 14.8 cm^2 (Turino et al., 2007; Rodrigues et al., 2008).

Table 5 - Initial weight, final weight, average daily gain, feed conversion and feed efficiency of lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
Inital weight (kg)	21.8	22.4	22.5	22.4	22.4	0.538	0.748[1]	0.772	0.871
Final weight (kg)	32.1	31.8	32.4	33.2	33.6	0.570	0.296[2]	0.722	0.742
Average daily gain (g)	97.4	88.5	93.4	101.2	105.3	4.810	0.403[3]	0.484	0.593
Feed conversion	6.8	8.1	7.8	7.2	7.0	0.307	0.892[4]	0.206	0.383
Feed efficiency	151.6	127.4	139.9	141.7	145.4	6.612	0.965[5]	0.426	0.464

SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] $\hat{Y}$ = 22.3.
[2] $\hat{Y}$ = 32.6;
[3] $\hat{Y}$ = 97.2.
[4] $\hat{Y}$ = 7.4.
[5] $\hat{Y}$ = 141.2.

Table 6 - Body weight at slaughter (BWS), hot carcass weight (HCW), cold carcass weight (CCW), hot carcass yield (HCY) and cold carcass yield (CCY) of lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
BWS (kg)	29.8	28.2	29.6	30.0	30.6	0.433	0.281[2]	0.360	0.372
HCW (kg)	13.3	13.7	13.6	13.6	14.4	0.255	0.209[3]	0.691	0.507
CCW (kg)	13.2	13.6	13.6	13.6	14.4	0.256	0.227[4]	0.706	0.558
HCY	44.4	48.6	46.0	45.4	47.4	0.712	0.579[1,5]	0.687	0.082
CCY	44.4	48.3	45.9	45.4	47.0	0.709	0.610[1,6]	0.676	0.098

SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] kg/100 kg of body weight.
[2] $\hat{Y}$ = 29.6.
[3] $\hat{Y}$ = 13.7.
[4] $\hat{Y}$ = 13.7.
[5] $\hat{Y}$ = 46.4.
[6] $\hat{Y}$ = 46.2.

Table 7 - Physical and color measurements of the carcass of lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
Conformation (1-5)	1.9	2.0	2.3	2.0	2.0	0.103	0.772[1]	0.336	0.828
Fattening status (1-5)	1.1	2.0	1.6	1.7	1.5	0.104	0.442[2]	0.113	0.367
Carcass length (cm)	64.7	65.8	66.0	66.1	66.2	0.377	0.314[3]	0.621	0.797
Leg length (cm)	39.7	39.0	37.8	39.0	39.0	0.303	0.543[4]	0.146	0.697
Leg width (cm)	7.1	8.5	7.8	7.9	8.1	0.144	0.193[5]	0.383	0.102
Chest depth (cm)	13.4	13.2	13.4	13.6	13.7	0.169	0.414[6]	0.699	0.718
Loin eye area (cm^2)	11.5	13.3	11.6	12.2	13.2	0.401	0.406[7]	0.723	0.301
Texture (1-5)	3.0	3.3	3.0	3.2	3.2	0.076	0.448[8]	0.950	0.606
Marbling (1-5)	1.2	1.3	1.6	1.2	1.2	0.105	0.918[9]	0.377	0.792
Color (1-5)	3.5	3.0	3.4	3.1	3.5	0.130	0.965[10]	0.457	0.901

SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] $\hat{Y} = 2.0$.
[2] $\hat{Y} = 1.6$.
[3] $\hat{Y} = 65.8$.
[4] $\hat{Y} = 38.9$.
[5] $\hat{Y} = 7.9$.
[6] $\hat{Y} = 13.5$.
[7] $\hat{Y} = 12.4$.
[8] $\hat{Y} = 3.2$.
[9] $\hat{Y} = 1.3$.
[10] $\hat{Y} = 3.3$.

The average fattening status value obtained in this work was 1.6 mm and can be explained by the genetic group and the animals' young age — on average 180-day-old at slaughter. Young animals tend to deposit and display lower fat levels in the carcass.

The potential of the Santa Ines breed to produce lean carcasses is very important information, thanks to the relevance given to the intake of lower-fat meat. However, a minimum fat cover is desirable for carcass protection, thus avoiding loss of water and burns from refrigeration of freezing.

The LEA observed was satisfactory, despite the low fatting status, because, according to Osório (1998), the average LEA varies from 2 to 5 mm, and the value obtained in this study was 1.6 mm, considered to be very lean.

The color and texture of the *longissimus dorsi* muscle are assessed because they affect the appearance of the cuts, and consequently, the consumer's acceptance. As to color, there were no significant differences (P>0.05) resulting from the levels of soybean hulls as substitute for corn.

Meat color is a very important quality factor that can be easily judged by consumers. It varies from a pinkish color, which denotes young animals, to a live red, the typical color of adult animals, and dark red, the color for old animals.

As regards texture, there was no significant effect (P>0.05) resulting from the levels of soybean hulls as substitute for corn, averaging 3.2 mm, which is a medium value, according to the rating scale by Osório (1998). Since the animals in the present study were young and in the same age range, the different diets were not sufficient to change meat texture according to treatment.

Inclusion of soybean hulls as substitute for corn had no influence (P>0.05) on the visual marbling of Santa Ines lamb meat, which averaged 1.3. When assessing F1 crossbred (Dorper × Santa Ines) and Santa Ines lambs, Cesar (2004) did not find any differences in marbling for the evaluated genetic groups.

There were no significant differences (P>0.05) in the weights of the various carcass cuts as a result of the levels of soybean hulls (Table 8). The good nutritional value of soybean hulls explains the obtained results. Since there was no significant effect on carcass yield, these results are consistent with anatomical harmony, according to which in carcasses with similar weights almost all body areas are found in similar proportion, regardless of the conformation of the considered genotype (Boccard and Dumont, 1960 apud Siqueira et al., 2001).

The average values for leg, rib, shoulder, neck, and loin weights were 2.2, 1.3, 1.4, 1.3, and 1.0 kg, respectively. The values obtained for rib, shoulder, neck and loin are higher than those found by Macedo et al. (2006), who found 0.62, 1.46, 0.49, and 0.61 kg, respectively, considering only half a carcass and slaughtering Bôer crossbred animals at 32 kg live weight. The yield of cuts from the carcass is one of the chief factors directly related to carcass quality (Sainz, 1996). There was no significant effect (P>0.05) on the yield of commercial cuts from the carcasses. The different cuts that make up the sheep carcass have different economic values and their proportions are an important parameter for

Table 8 - Weight and yield of commercial cuts from the carcasses of Santa Ines lambs fed diets containing different levels of soybean hulls as substitute for corn

Item	Level of soybean hulls					SEM	P-value		
	0	250	500	750	1,000		L	Q	C
				Leg					
kg	2.1	2.2	2.2	2.2	2.3	0.039	0.292[1]	0.892	0.856
g/kg	319.6	320.2	320.5	327.4	317.0	0.181	0.886[2]	0.322	0.202
				Rib					
kg	1.2	1.6	1.3	1.3	1.3	0.047	0.876[3]	0.303	0.080
g/kg	179.6	227.9	188.7	194.2	187.2	0.578	0.654[4]	0.187	0.081
				Shoulder					
kg	1.3	1.4	1.3	1.4	1.4	0.027	0.357[5]	0.907	0.559
g/kg	201.1	204.0	199.0	203.8	198.2	0.178	0.646[6]	0.639	0.849
				Neck					
kg	1.3	1.4	1.3	1.4	1.4	0.033	0.376[7]	0.862	0.729
g/kg	195.3	199.7	191.1	201.6	196.0	0.303	0.873[8]	0.975	0.889
				Loin					
kg	0.9	1.0	0.9	1.0	1.0	0.022	0.059[9]	0.768	0.772
g/kg	133.2	140.5	139.7	146.8	141.7	0.1395	0.027[10]	0.165	0.681

SEM - standard error of the mean; L - linear; Q - quadratic; C - cubic.
[1] $\hat{Y} = 2.2$.
[2] $\hat{Y} = 320.9$.
[3] $\hat{Y} = 1.3$.
[4] $\hat{Y} = 195.0$.
[5] $\hat{Y} = 1.4$.
[6] $\hat{Y} = 201.0$.
[7] $\hat{Y} = 1.3$.
[8] $\hat{Y} = 197.0$.
[9] $\hat{Y} = 1.0$.
[10] $\hat{Y} = 140.4$.

their commercial assessment. However, literature points to genetics, gender, body weight, type of diet, and number of hours fasting as possible causes for variations in the values of these components (Pilar et al., 2002).

Conclusions

Substituting corn for up to 1,000 g/kg soybean hulls in the concentrates of confined lambs increases the intake of dry matter and of most nutrients. Soybean hulls can substitute corn at up to 1,000 g/kg of concentrates for lambs without affecting digestibility, performance, or carcass characteristics.

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