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Performance, ingestive behavior and carcass traits of lambs fed rations containing soybean cake

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ABSTRACT. The aim of this study was to evaluate the performance, ingestive behavior and carcass traits of crossbred Dorper x Santa Inês lambs fed rations containing soybean cake. Twenty-four lambs (4 months of age and 24.3 ± 3.1 kg BW) were used in a completely randomized design with four treatments and six replicates. Treatments were the inclusion of 50, 100 or 150 g kg^{-1} of soybean cake in the ration, on a DM basis, and a control diet without this ingredient. Rations were offered *ad libitum* for 75 days and the lambs were slaughtered at 35 to 40 kg BW. Dry matter intake reduced linearly and the average daily gain had a quadratic response to the soybean cake levels, also decreasing with the addition of this ingredient. The time spent feeding increased and the idle time decreased linearly with the soybean cake levels, whereas the time spent in rumination was not affected. Hot and cold carcass weights decreased linearly with the addition of this ingredient. The addition of 50 to 150 g kg DM^{-1} of soybean cake to the ration for lambs is not recommended due to reduced animal performance, which may compromise the profitability of sheep farmers.

Keywords: carcass weight; ether extract; fat, feedlot; neutral detergent fiber; time spent on feeding.

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Introduction

The production of protein for human consumption has been a major concern for world authorities due to the growing world population, especially in developing countries. It is estimated that the world population will increase from 7.4 to 8.1 billion between 2016 and 2025, and 95% of this increase will occur in developing countries (Food and Agriculture Organization of the United Nations [FAO], 2017). Considering this, it is important to encourage the production of good quality and low cost food, mainly for the poor population. In this sense, sheep production has great productive potential, but it is still not very common in Brazil, compared to beef and dairy cattle production. However, sheep production increased 3.4 times more than cattle production (4.52 *vs.* 1.34%) in Brazil between 2014 and 2015 (Instituto Brasileiro de Geografia e Estatística [IBGE], 2015), which currently has a herd of approximately 17.98 million heads, distributed mainly in the northeastern (64.2%) and southern (23.7%) regions (IBGE, 2017).

The consumption of sheep meat in different regions of the world is determined by a combination of factors, such as consumer purchasing power, dietary preferences, tradition or culture, and competition with other sources of protein (Sañudo, Sanchez, & Alfonso, 1998; Sañudo, Muela, & Campo, 2013). Although the consumption of sheep meat in Brazil is still low, there is a strong expectation that it will increase since the importation of this product has grown in recent years, with 80% of the total imported volume coming from Uruguay (Viana, Moraes, & Dorneles, 2015). Moreover, this indicates that the Brazilian sheep meat production chain needs to be adjusted to improve production rates in order to meet its domestic demand.

The use of animals with high growth potential and the improvement of sanitation and feeding management are tools that can increase meat production. Regarding the production systems, feedlots are known to have a great impact on the production of high quality meat in a short time frame. However, the high cost of production may be a limiting factor to the adoption of this strategy by the farmers. In this way, it is of great importance to find alternative sources of good quality feedstuffs for sheep, especially for finishing lambs.

The use of biodiesel industry byproducts in animal nutrition is a way to reduce their environmental damage. Most of these byproducts may meet the demands of the animal production sector for good quality and low cost feedstuffs, becoming an alternative to feedlot feeding. These issues have motivated some researchers to study different byproducts associated with different rearing conditions for cattle and sheep (Abdalla, Silva Filho, Godoi, Carmo, & Eduardo, 2008; Oliveira et al., 2012; Françozo et al., 2013; Eiras et al., 2014). However, there is no recommendation for the use of the main byproducts from biodiesel production (soybean, cottonseed, palm, castor and sunflower cakes) for ruminant nutrition.

One of the main factors that limit the use of these byproducts in ruminant feed is their high oil content. In this case, the animals' performance may be reduced due to low fiber degradability, caused by an excess of lipids in the feed (Van Soest, 1994; Berchielli, Pires, & Oliveira, 2011). On the other hand, studies developed in Australia and Canada noted that the addition of 1% of lipids to the diet can contribute to a 6% reduction in the methane produced per kilogram of dry matter (DM) consumed by ruminants (Grainger, Williams, Clarke, Wright, & Eckard, 2010; Monteiro et al., 2018).

The aim of this study was to evaluate the performance, ingestive behavior and carcass traits of crossbred Dorper x Santa Inês lambs fed rations containing four levels of soybean cake.

Material and methods

All the procedures of this research were performed in accordance with the Ethical Principles in Animal Experimentation adopted by the Brazilian College of Animal Experimentation (Colégio Brasileiro de Experimentação Animal – COBEA) and were approved by the Animal Care and Use Committee (Comitê de Ética no Uso de Animais – CEUA) of the Federal University of Paraná (Universidade Federal do Paraná – UFPR), Palotina Campus, under protocol number 03/2012-CEUA.

The experiment was conducted at the Center of Studies in Small Ruminants (Centro de Estudos em Pequenos Ruminantes – CEPER) located on the Palotina Campus of the Federal University of Paraná, Paraná state, Brazil. Twenty-four non-castrated male crossbred Dorper x Santa Inês lambs, with an average age of 4 months and an average body weight (BW) of 24.26 ± 3.10 kg were used. The animals were allocated to covered individual pens, with a slatted floor and an area of 1.5 m^2. These pens had individual feeders and water drinkers. Lambs were kept in these pens for 75 days from August to October; the first 15 days were an adaptation period to the experimental management, and the last 60 days comprised the experimental period. The average temperature inside the barn during the experiment was 25°C.

The lambs were identified with ear tags, weighed on a scale with 0.2 kg precision and dewormed (Ivermectin applied subcutaneously at a dose of 1 mL 50 kg BW^{-1}) at the beginning of the adaptation period. After these practices, the treatments were assigned to each lamb following a completely randomized design with four treatments and six replicates. The treatments were the inclusion of 50.0, 100.0 and 150.0 g kg^{-1} of soybean cake in the ration, on a DM basis, and a control diet without this ingredient.

The rations, formulated based on the recommendations of the National Research Council (NRC, 1985) to meet the requirements for an average daily gain (ADG) of 250 g day^{-1}, were composed of Tifton hay, commercial pelleted concentrate, ground corn, soybean cake and mineral supplement (Tables 1 and 2), and contained 151.4 g kg DM^{-1} of crude protein (CP) and 649.7 g kg DM^{-1} of total digestible nutrients (TDN), on average (Table 2). The rations were supplied as total mixed ration (TMR) and split into two daily meals (08h00 and 14h00). The animals were fed *ad libitum* during the adaptation period and the experiment, such that the orts were kept at 10% of the amount of feed provided. The rations were supplied at 5.0% of the lambs' BW on the first day of the adaptation period; from this day, adjustments of the amount of ration supplied were performed every week based on the amount of orts.

The orts of each animal were collected before the morning meal, and weighed and stored in plastic bags daily. At the end of each week, composite samples were formed from the orts collected over the previous 7 days. Subsamples of the composite samples from each week were collected and stored in a freezer at -4°C. The subsamples were thawed at the time of the chemical analysis, and representative composite samples from the experimental period were formed and sent for analysis.

The daily intake of dry matter (DMI), crude protein (CPI), ether extract (EEI), neutral detergent fiber (NDFI) and total digestible nutrients (TDNI) was calculated for each animal as the difference between the amount of DM and nutrients in the provided feed and in the orts. DMI was expressed in g day^{-1} and % BW day^{-1}, and the nutrients intake was expressed only in g day^{-1}.

Table 1. Dry matter content (g kg^{-1} of natural matter – NM) and chemical composition (g kg^{-1} of dry matter – DM) of the feedstuffs used in the experimental rations.

Component	Ingredients				
	Tifton hay	Commercial concentrate[I]	Ground corn	Soybean cake	MV premix[II]
Dry matter	890.0	887.1	900.0	890.0	1000.0
Crude protein	100.0	180.0	70.0	450.0	-
Ether extract	20.0	25.0	37.0	166.0	-
Neutral detergent fiber	700.0	211.4	90.0	170.0	-
Calcium	2.4	23.3	3.0	3.0	220.0
Phosphorus	1.0	6.1	5.0	7.5	75.0
Total digestible nutrients	540.0	757.7	800.0	900.0	-

[I]Pelleted concentrate composed of 475 g kg^{-1} ground corn, 320 g kg^{-1} wheat meal, 100 g kg^{-1} soybean meal; 40 g kg^{-1} mineral and vitamin premix (same added in the rations), 25 g kg^{-1} limestone, 25 g kg^{-1} flavoring and 15 g kg^{-1} urea, on DM basis. [II]Mineral and vitamin premix. Guaranteed analysis – Macrominerals: 220 g kg^{-1} calcium, 75 g kg^{-1} phosphorus, 12 g kg^{-1} magnesium and 133 g kg^{-1} sodium; Trace minerals: 200 mg kg^{-1} cobalt, 1400 mg kg^{-1} iron, 177 mg kg^{-1} iodine, 2250 mg kg^{-1} manganese, 23 mg kg^{-1} selenium and 4500 mg kg^{-1} zinc; Vitamins: 100000 UI kg^{-1} vit A, 60 UI kg^{-1} vit E and 65000 UI kg^{-1} vit D3.

Table 2. Proportion of ingredients and chemical composition (both in g kg^{-1} dry matter – DM) of the experimental rations.

Components	Soybean cake (g kg^{-1} DM)			
	0	50	100	150
Ingredients				
Tifton hay	340.0	500.0	650.0	590.0
Commercial concentrate	650.0	440.0	240.0	50.0
Ground corn	0.0	0.0	0.0	200.0
Soybean cake	0.0	50.0	100.0	150.0
Mineral supplement	10.0	10.0	10.0	10.0
Chemical composition				
Dry matter	889.2	889.8	890.4	893.0
Crude protein	151.0	151.7	153.2	149.5
Ether extract	23.1	29.3	35.6	45.4
Neutral detergent fiber	375.4	451.5	522.7	467.1
Calcium	18.2	13.8	9.7	5.8
Phosphorus	5.1	4.3	3.6	3.8
Total digestible nutrients	676.1	648.4	622.9	651.5

Orts samples were dehydrated in a forced air ventilation oven at 65°C for 72h, and subsequently processed in a Wiley knife mill with a 1 mm mesh sieve. The chemical analysis included the quantification of DM, CP, ether extract (EE) and ash, according to the methods proposed by the Association of Official Analytical Chemists (AOAC, 2005) and neutral detergent fiber (NDF), according to the methodology described by Van Soest, Robertson, and Lewis (1991). From these nutrients, the non-fibrous carbohydrate (NFC) was calculated according to Hall, Hoover, Jennings, and Webster (1999) and TDN were calculated according to Weiss, Conrad, and Pierre (1992). Drying, sample processing and chemical analysis were performed at the Laboratory of Animal Nutrition of the Federal University of Paraná, Palotina Campus.

Lamb performance was evaluated using weight measurements on the first and last days of the experimental period. Weights were measured early in the morning after fasting (the withdrawal of feed for 14 hours). ADG (g day^{-1}) was obtained by the difference between the initial and final BW, divided by the number of days of the experimental period (60 days). The feed conversion ratio (FCR, g DM g gain^{-1}) was calculated as the ratio between DMI and ADG.

Feeding behavior was evaluated for 24 hours on the 15th and 45th days of the experimental period. The evaluations were made by eight trained observers, who were divided into four pairs; each pair evaluated the lambs for 6 hours. Feeding, rumination (while standing and lying), water intake and idle activities were identified and recorded every 10 minutes, according to the method of Martin and Bateson (1993). During the night, flashlights were used to allow the visualization of these activities.

All lambs were slaughtered at 35 to 40 kg BW. Upon reaching this BW range, lambs were fasted, weighed to record body weight at slaughter (SW) and sent to a commercial slaughterhouse in the region. This establishment is registered through the Municipal Inspection Service (Serviço de Inspeção Municipal – SIM). The slaughter was conducted in accordance with good animal welfare practices, in which the animals were stunned, followed by bleeding (performed by severing the jugular veins and carotid arteries), skinning and evisceration. After the animals were slaughtered, carcasses were weighed to record the hot carcass weight (HCW), identified and suspended by the metatarsal joints. Then, the carcasses were transferred to a cold room at 4°C, where they remained for 24 hours. After the cooling process, the carcasses were weighed to record the cold carcass weight (CCW). The SW, HCW and CCW were used to calculate the hot carcass yield [$\text{HCY} = (\text{HCW}/\text{SW}) \times 100$], the commercial or cold carcass yield [$\text{CCY} = (\text{CCW}/\text{SW}) \times 100$] and the cooling loss [$\text{CL} = [(\text{HCW} - \text{CCW})/\text{HCW}] \times 100$].

The data were analyzed by regression (PROC REG), in which the ration soybean cake content was considered the independent variable. The analyses were performed up to the second order (quadratic), according to the following model:

$$\hat{Y}_{ij} = \beta_0 + \beta_1 Ai_1 + \beta_2 Ai_2 + \gamma_{ij} + \varepsilon_{ij},$$

where: $\hat{Y}_{ij}$ = value of the dependent variable for the j_{th} lamb in the i_{th} soybean cake content; β_0 = regression intercept; A_i = independent variable; β_1 = linear regression coefficient for the dependent variable; β_2 = quadratic coefficient of regression for the dependent variable; γ_{ij} = regression deviations; ε_{ij} random error. An orthogonal contrast (PROC GLM) was used to compare the control diet with all rations containing soybean cake. Probability values lower than 0.05 were considered significant, whereas values between 0.05 and 0.10 were considered trends. The analyses were performed in the Statistical Analysis System, version 9.0 (Statistical Analysis System [SAS], 2002).

Results and discussion

Despite being within the range (1000 to 1300 g day^{-1}) recommended by the NRC (1985) for lambs with moderate to fast growth rates (200 to 250 g day^{-1}), DMI reduced linearly ($p = 0.0683$) with soybean cake levels (Table 3). This trait reduced from 1344.2 to 1223.3 g day^{-1} between the rations without and with 150 g kg DM^{-1} of soybean cake, which corresponded to a difference of 120.9 g day^{-1} and represented a 9.0% reduction. The DMI_{BW} was not influenced ($p > 0.05$) by the addition of soybean cake and showed a mean value of 3.99% BW day^{-1}. This value is slightly lower than that recommended by the NRC (1985), which is 4.30 to 5.00% BW day^{-1}.

Since the rations had approximately the same CP content (Table 2), the CPI was not influenced ($p > 0.05$) by the addition of soybean cake (Table 3). However, EEI increased linearly ($p < 0.0001$) from 31.0 to 44.2 g day^{-1} between 0 and 150 g kg DM^{-1} of soybean cake. This is related with the high EE content of soybean cake (Table 1), such that the addition of this ingredient to the ration led to an increase of its EE content and, hence, an increase in the intake of this nutrient by the lambs. Similar results were reported by Oliveira et al. (2012) for crossbred Boer kids fed rations with sunflower cake (*Helianthus annuus*) and for lambs fed rations containing African oil palm cake (*Elaeis guineensis*), and by Lima et al. (2018) for lambs fed rations with sunflower cake.

The NDFI showed a quadratic response ($p = 0.0213$) to the soybean cake levels and increased from 236.7 to 468.3 g day^{-1} between 0 and 150 g kg DM^{-1} of soybean cake. This reflects the changes in NDF content among the rations, which also showed a quadratic effect ($\text{NDF} = 369.31 + 2.6691\ \text{SC} - 0.01320\ \text{SC}^2$; $R^2 = 0.933$; SC = soybean cake) with the levels of soybean cake. The maximum NDFI was verified at the levels of 100 and 150 g kg DM^{-1} of soybean cake, where the ration with 100 g kg DM^{-1} of soybean cake had the highest NDF content (522.7 g kg DM^{-1}; Table 2). This variation in the NDF content of the rations is related to the increase in the addition of Tifton hay, up to the level of 100 g kg DM^{-1} of soybean cake, which was performed to obtain the same energy: protein balance among the rations.

Table 3. Means and standard error of the mean (SEM) for the performance traits of feedlot lambs fed rations with increasing levels of soybean cake.

Variables[I]	Soybean cake (g kg^{-1} DM)[I]					SEM	*P*-value[II]		
	0	50	100	150	SC[III]		Lin	Quad	0 x SC
DMI	1344.2	1284.2	1210.8	1223.3	1239.4	0.27	0.0683	0.4934	0.0940
DMI_{BW}	4.09	4.08	3.87	3.94	3.96	0.06	0.2162	0.7374	0.3628
CPI	225.0	219.2	210.0	225.0	218.1	0.04	0.8227	0.2564	0.5129
EEI[IV]	31.0	35.9	38.8	44.2	39.7	1.00	<0.0001	0.8597	<0.0001
NDFI[IV]	236.7	330.0	468.3	468.3	422.2	0.17	<0.0001	0.0213	<0.0001
TDNI	890.8	827.5	755.8	823.3	802.2	0.18	0.0933	0.0668	0.0330
ADG[IV]	285.0	240.0	223.3	226.7	230.0	0.06	0.0004	0.0286	<0.0001
FCR	4.73	5.54	5.51	5.40	5.48	0.14	0.1140	0.0998	0.0216

[I]DM: dry matter; DMI: dry matter intake (g day^{-1}); DMI_{BW}: DMI relative do the body weight (% BW day^{-1}); CPI: crude protein intake (g day^{-1}); EEI: ether extract intake (g day^{-1}); NDFI: neutral detergent fiber intake (g day^{-1}); TDNI: total digestible nutrients intake (g day^{-1}); ADG: average daily gain (g day^{-1}); FCR: feed conversion ratio (g DM g gain^{-1}). [II]Lin: linear regression; Quad: quadratic regression; 0 x SC: comparison of ration without soybean cake with all rations containing this ingredient. [III]Mean values for all rations with soybean cake. [IV]Regression equations: $\text{DMI} = 1.3310 - 0.0087\ \text{SC}\ (R^2 = 0.840)$; $\text{EEI} = 31.12 + 0.0852\ \text{SC}\ (R^2 = 0.988)$; $\text{NDFI} = 227.54 + 3.0657\ \text{SC} - 0.00933\ \text{SC}^2\ (R^2 = 0.956)$; $\text{TDNI} = 898.21 - 2.5110\ \text{SC} + 0.01310\ \text{SC}^2\ (R^2 = 0.881)$; $\text{ADG} = 284.59 - 1.1092\ \text{SC} + 0.00483\ \text{SC}^2\ (R^2 = 0.999)$; $\text{FCR} = 4.765 + 0.0178\ \text{SC} - 0.00009\ \text{SC}^2\ (R^2 = 0.937)$.

TDNI had a quadratic response (p = 0.0668) to the soybean cake levels (Table 3) and showed an inverse response to the NDFI. Thus, the lowest TDNI was observed at the level of 100 g kg DM^{-1} of soybean cake, which is possibly related to the lower digestibility of fibrous components and, hence, the lower energy bioavailability in this ration. Although the levels of 100 and 150 g kg DM^{-1} of soybean cake led to the same NDFI, the TDNI was higher in the latter ration. This occurred because the EEI increased with soybean cake levels and the lower energy content of NDF was compensated by the higher energy content of EE, increasing the TDNI in the ration with 150 g kg DM^{-1} of soybean cake.

Because the quadratic equation for NDFI did not have an inflection point, its variation among the soybean cake levels was approximately linear. This may explain the linear decrease of DMI with the addition of soybean cake (Table 3). Oliveira et al. (2012) reported a linear decrease in DMI and a linear increase in NDFI for feedlot lambs fed rations with African oil palm cake, which was related to the high NDF content of this ingredient (700.0 to 818.0 g kg DM^{-1}). Lima et al. (2018) verified that both DMI and NDFI decreased linearly with the sunflower cake levels in the ration provided to feedlot lambs. These authors also observed a linear decrease in DM digestibility, which was determined by the limited action of ruminal microorganisms on food particles due to the presence of unsaturated fatty acid in the sunflower cake. The digestibility of DM and nutrients was not assessed in the present study; however, it is possible that the increase of NDFI and EEI with soybean cake levels led to a reduction in the digestibility of the diet, reducing the DMI of the lambs. Although the EE content of the rations (ranging from 23.1 to 45.5 g kg DM^{-1} between 0 and 150 g kg DM^{-1} of soybean cake; Table 2) was lower than the maximum limit tolerable by ruminants (70.0 g kg DM^{-1} according to Van Soest [1994]), its increase with the addition of soybean cake may have impaired fiber fermentation in the rumen. Moreover, higher EEI and NDFI, and lower DMI were observed in the rations with 100 and 150 g kg DM^{-1} of soybean cake (Table 3), which reinforces this hypothesis.

The ADG had a quadratic response (p = 0.0286) to the soybean cake levels, reaching the lowest value of 220.9 g day^{-1} at the level of 114.8 g kg DM^{-1} of soybean cake, based on the regression equation (Table 3). The difference between the lowest ADG value and that obtained for the ration without soybean cake was 64.1 g day^{-1}, which corresponds to a 22.5% reduction of this trait. Pompeu et al. (2012) and Gomes, Cândido, Carneiro, Furtado, and Pereira (2017) reported a reduction in the ADG of lambs fed rations containing castor cake (*Ricinus communis*). The former authors verified that ADG decreased linearly (from 197 to 130 g day^{-1}), which was related to the high oil and ricinoleic acid contents of this ingredient. In the study by Gomes et al. (2017), higher ADG was obtained for the ration containing autoclaved castor cake (156 g day^{-1}) compared to rations containing non-treated (117 g day^{-1}) or urea-treated castor cake (115 g day^{-1}), which is explained by the elimination of ricin during the autoclaving process and, therefore, the better efficiency of utilization of the diet consumed by the lambs. Lima et al. (2018) also verified that lambs' ADG decreased linearly (from 220 to 120 g day^{-1}) with sunflower cake levels, which was a consequence of the high EEI and low DM digestibility determined by this ingredient.

The FCR had a quadratic response (p = 0.0998) to the soybean cake levels (Table 3), with an inverse response to ADG. Based on the regression equation, the highest value for FCR (5.65 g DM g $gain^{-1}$) could be obtained with the addition of 98.9 g kg DM^{-1} of soybean cake to the ration. The difference between the estimated value and that obtained for the ration without soybean cake was 0.92 g DM g $gain^{-1}$, which represents a 19.4% increase in the FCR. The increase of lipids content with the addition of oilseed cake to the ration can help to mitigate methane production and, therefore, it is beneficial to the ruminants (Abdalla et al., 2008; Grainger et al., 2010; Monteiro et al., 2018). In this sense, animal performance can be improved due a reduction of the FCR, since rations with high lipids content tend to reduce the DMI but do not affect the ADG (Valinote, Nogueira Filho, Leme, Silva, & Cunha, 2005). In the present study, both DMI and ADG were reduced with the addition of soybean cake, leading to a reduction in lamb performance; this affected the feed efficiency of these animals, resulting in a higher FCR.

Feeding time was affected by the soybean cake levels, with a linear increase (p = 0.0008) from 200 to 280 min day^{-1} for the rations without and with 150 g kg DM^{-1} of soybean cake (Table 4). This 40.0% increase in feeding time is attributed to the increase of NDFI among the rations, since the high fiber intake leads to an increase in the time spent feeding (Van Soest, 1994; Berchielli et al., 2011). Also, the fiber content is inversely related to the net energy content of the diet and, once there is an increase to the NDFI, there is an increase in the time spent feeding in order to guarantee the supply of energy requirements (Mertens, 1996).

Table 4. Means and standard error of the mean (SEM) for the time spent (min) in activities related to ingestive behavior in feedlot lambs fed rations with increasing levels of soybean cake.

Variable	Soybean cake (g kg^{-1} DM)[I]					SEM	P-value[II]		
	0	50	100	150	SC[III]		Lin	Quad	0 x SC
Feeding[IV]	200	238	286	280	268	10.0	0.0008	0.2201	0.0019
Rumination	618	592	578	588	586	11.1	0.3118	0.4350	0.2356
while standing	41	40	33	33	35	4.6	0.4354	0.9039	0.5625
while lying	576	552	546	555	551	10.1	0.4460	0.4228	0.2961
Water intake	21	21	18	19	19	1.1	0.4245	0.8666	0.5859
Idleness[IV]	602	589	558	553	567	11.6	0.0846	0.8507	0.1893

[I]DM: dry matter. [II]Lin: linear regression; Quad: quadratic regression; 0 x SC: comparison of ration without soybean cake with all rations containing this ingredient. [III]Mean values for all rations with soybean cake. [IV]$F = 207.54 + 0.5775\ SC\ (R^2 = 0.859)$; $I = 602.44 - 0.3570\ SC\ (R^2 = 0.929)$.

The mean value for the time spent feeding (251 min day^{-1}) was lower than those found by Syperreck et al. (2016) and Gomes et al. (2017) for feedlot lambs fed rations containing oilseed cakes, which reported mean values of 299 and 331 min day^{-1}, respectively. This may be associated with the higher NDF content of the rations evaluated in those studies (661.5 and 543.0 g kg DM^{-1}, respectively) compared to the rations used in the present study (ranging from 375.4 to 522.7 g kg DM^{-1}; Table 2). However, in the literature, there is great variation in feeding time, which is mainly attributed to the characteristics of the rations provided to feedlot lambs.

The total rumination time and the time spent ruminating while standing or lying were not affected ($p > 0.05$) by the addition of soybean cake to the ration (Table 4), with mean values of 594, 37 and 557 min day^{-1}, respectively. Although the NDFI showed a quadratic response to the soybean cake levels, this variation in fiber intake not affected the rumination time. This result is not in accordance with that obtained by Syperreck et al. (2016), who reported an increase in rumination time (421 to 497 min day^{-1}) with an increase of the roughage:concentrate ratio, from 300 to 700 g kg DM^{-1} in rations composed of sorghum silage and crambe cake. In this case, the increase of rumination activity was related to the high content of large fibrous particles in the ration with higher roughage content. On the other hand, Cardoso et al. (2006) noted a linear increase in NDFI, but did not find an increase in rumination time (mean of 483 min day^{-1}) when the NDF content increased from 250 to 430 g kg DM^{-1} in the rations for feedlot lambs. These results demonstrate that rumination activity is influenced by the increase of large fibrous particle content in the ration, and by a great change in the NDF content from the addition of roughage to the diet. The lack of an effect of the NDFI on the rumination time is probably explained by the similar physical characteristics of the roughage, and the low variation in its content between the rations (only 147.3 g DM^{-1} or 14.73% difference between the ration with the lowest and greatest NDF content).

The time spent on water intake was not affected ($p > 0.05$) by the addition of soybean cake to the ration (Table 4), and showed a mean value of 20 min day^{-1}. Gomes et al. (2017) also did not find an effect of rations containing castor cake, submitted to different detoxification methods, on the water intake of feedlot lambs (mean of 12 min day^{-1}). With the linear increase in the time spent feeding, the idle time decreased linearly ($p = 0.0846$) from 602 to 553 min day^{-1} for the rations without and with 150 g kg DM^{-1} of soybean cake.

The mean value for SW was 38.91 kg, which was within the pre-established range for this trait in the experiment (35 to 40 kg). However, the decrease in ADG led to a linear decrease ($p = 0.0583$) of SW with the soybean cake levels (Table 5), which reduced from 41.88 to 37.56 kg for the rations without and with 150 g kg DM^{-1} of soybean cake.

For the carcass traits, only HCW and CCW were influenced by the soybean cake levels; they both decreased linearly ($p = 0.0469$ and $p = 0.0451$, respectively) from 19.02 to 16.20 kg, and from 18.39 to 15.59 kg for the rations without and with 150 g kg DM^{-1} of soybean cake. These results are explained by the reduction of the lambs' ADG, resulting in lighter carcasses for the lambs fed the ration containing 150 g kg DM^{-1} of soybean cake. The HCY, CCY and CL were not affected ($p > 0.05$) by the soybean cake levels and presented mean values of 43.96, 42.40 and 3.55% respectively. The decrease of carcass weights, without affecting the carcass yields and CL, suggests that the addition of soybean cake led to a low muscle deposition and a similar fat deposition on the carcasses. In fact, the carcass yields may be associated with fat deposition (Kremer et al., 2004), and the increase of EEI with the soybean cake levels probably contributed to this tissue accretion due to the high energy content of lipids.

Table 5. Means and standard error of the mean (SEM) for the carcass traits of feedlot lambs fed rations with increasing levels of soybean cake.

Variables[I]	Soybean cake (g kg^{-1} DM)[I]					SEM	P-value[II]		
	0	50	100	150	SC[III]		Lin	Quad	0 x SC
SW[IV]	41.88	39.31	36.87	37.56	37.91	0.92	0.0583	0.3582	0.0660
HCW[IV]	19.02	17.20	16.13	16.20	16.51	0.54	0.0469	0.3635	0.0497
CCW[IV]	18.39	16.59	15.57	15.59	15.92	0.53	0.0451	0.3697	0.0485
HCY	45.30	43.66	43.89	43.01	43.52	0.77	0.3410	0.8107	0.3448
CCY	43.79	42.11	42.34	41.38	41.94	0.75	0.3056	0.8143	0.3156
CL	3.34	3.56	3.51	3.81	3.62	0.10	0.1260	0.8403	0.2255

[I]DM: dry matter; SW: slaughter weight (kg); HCW: hot carcass weight (kg); CCW: cold carcass weight (kg); HCY: hot carcass yield (%); CCY: cold carcass yield (%); CL: cooling losses (%). [II]Lin: linear regression; Quad: quadratic regression; 0 x SC: comparison of ration without soybean cake with all rations containing this ingredient. [III]Mean values for all rations with soybean cake. [IV]Regression equations: $SW = 41.219 - 0.0308\ SC$ ($R^2 = 0.794$); $HCW = 18.565 - 0.0190\ SC$ ($R^2 = 0.835$); $CCW = 17.949 - 0.0188\ SC$ ($R^2 = 0.841$).

The carcass yield results are contrary to those found by Pompeu et al. (2012), who verified a linear decrease of these traits (HCY = 48.8 to 46.2%; CCY = 47.5 to 45.3%) with the addition of castor cake to the ration. Also, the values reported by these authors and those found by Cunha, Carvalho, Gonzaga Neto, and Cezar (2008) and Silva et al. (2016) for the carcass yields of feedlot lambs fed rations containing whole cottonseed (HCY = 47.64% and CCY = 46.60%) and sunflower cake (HCY = 48.65% and CCY = 46.70%), respectively, were higher than those obtained in the present study. This is explained by the lower SW (ranging from 30.20 to 32.18 kg) and differences related to the breeds and rations tested in these studies. According to Ramírez-Retamal and Morales (2014), animal breed and type of food have a great influence on the carcass yields of sheep, and values ranging from 40.90 to 70.10% for HCY and from 38.90 to 68.40% for CCY may be observed in sheep raised on pasture and finished in feedlot with concentrate-based diets, respectively.

Regarding the CL, the mean value obtained in the present study (3.65%) was higher than that reported by Cunha et al. (2008) and lower than that found by Silva et al. (2016), with mean values of 2.10 and 3.85%, respectively. This trait is also associated with fat deposition in the carcass, especially the fat covering thickness, and the maximum tolerable values range from 3.00 to 4.00% for lambs carcasses (Almeida Júnior et al., 2004). Thus, even with the decrease of HCW and CCW caused by the soybean cake addition, the CL remained within the tolerable range, which indicates that carcasses from the present study showed fat statuses suitable for marketing and, hence, were of good quality among the tested rations.

The orthogonal contrast analysis demonstrated that the addition of 50 to 150 g kg DM^{-1} of soybean cake to the ration was the main factor that affected ($p < 0.05$) the performance traits (except DMI_{BW} and CPI; Table 3), the time spent feeding (Table 4), SW, HCW and CCW (Table 5). Given the negative effects of this feedstuff on all of these traits, its use in rations for feedlot lambs is not technically recommended.

Conclusion

Rations containing 50 to 150 g kg^{-1} of soybean cake, on a dry matter basis, impair the performance of lambs and may compromise the profitability of sheep farmers.

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