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The lipid source can modify saturated and unsaturated fatty acids profile of meat of lambs

Bruna Junqueira RODRIGUES[1], Camila Celeste Brandão Ferreira ÍTAVO[1], Luís Carlos Vinhas ÍTAVO[1*], Marina de Nadai Bonin GOMES[1], Gelson dos Santos DIFANTE[1], Thais Fernanda Farias de Souza ARCO[1], Antonio Leandro Chaves GURGEL[1], Larissa Marques HIGANO[1], Camila de GODOY[1], Aline Aparecida da Silva MIGUEL[1], Gabriella Vitor de SOUZA[1], Rosanne Cristine da Silva LUZ[1], Bárbara Martins BRIXNER[1]

Abstract

We hypothesize that lambs fed diets with different lipids sources from oilseeds would similar performance but fatty acids profile of meat superior to those fed with conventional diets. We evaluated the effects of inclusion of oilseeds on the ingestive behaviour, performance, carcass trait and meat quality in feedlot lambs. Three isonitrogenous (18.31% crude protein) diets were evaluated, where one diet was the standard (control), and the others two diets contained soybean and cottonseed. Fifteen Texel lambs, weighting 28.5 ± 1.65 kg were distributed in a completely randomized design by 56 days. Animals fed soybean diet demonstrated greater final body weight when compared to animals fed cottonseed diet and standard diet. The inclusion of cottonseed provided lower average daily gain and total weight gain. Ingestive behaviour of the animals fed diets with grains resulted in greater rumination time. Lambs fed cottonseed diet spent greater time during rumination and presented greater number of chews/day. The hot carcass and cold carcass weight presented lower values in animals fed cottonseeds diet. There was no significant difference in meat for marbling, maturity, fat texture and shear force. Meat from animals fed soybean diet had highest fat content. There was a diet effect for fatty acids composition in the meat. Meat of lambs treated with soybean have greater amounts for fatty acids mostly the unsaturated ones, related to the decrease in cholesterol levels, and lower risk of cardiovascular diseases, thus, lambs fed soybean enrich meat produced with fatty acids that benefit human health.

Keywords: carcass; conjugated linoleic acid; cottonseed; soybean; meat quality.

Practical Application: This research contributes to investigate diets with lipid sources capable of altering the fatty acid profile of lamb meat.

1 Introduction

Lipid supplementation may promote physiological benefits to the digestive process of animals and reduce losses in energy metabolism (Oliveira et al., 2011). In certain circumstances, these benefits represent an alternative for production of heavier animals presenting greater dressing percentage and typical tissue composition, which may be beneficial to the consumer health. Oilseed grains such as cottonseed and soybean have been shown to be used as good lipid source in ruminant diets because of their high unsaturated fatty acids content. The inclusion of these grains raises the energy density of the rations fed to the animals, improves performance and manipulates the quality of meat and carcass (Bassi et al., 2012).

Lipids are composed of organic structures, most of which are produced by the union of three fatty acids and one glycerol, forming a structure known as triglyceride, which makes up about 98% of the fat in foods. The fatty acids that make up the lipids belong to two groups: saturated fatty acids and unsaturated fatty acids. The saturation state is an important chemical as well as nutritional characteristic, and chemically, the saturated fatty acids are those with no double bonds in their structure and the unsaturated fatty acids are those with double bonds (Lehninger et al., 2000).

Although fatty acids have great potential for use some issues are still not fully understood, such as their effects on carcass traits and the quality of lamb meat. It is known that the quality, composition, and lipid profile of ruminant meat can be altered by the source of lipids supplied to the animals via diet (Bassi et al., 2012; Pereira et al., 2016) and, therefore, we hypothesize that male lambs fed diets with different sources of lipids would perform similarly to those who receive a conventional diet, however, the characteristics of the carcass, quality, and composition of meat superior to those fed with conventional diets. In this context, the objective of this study was to evaluate the effect of diets containing oilseeds (soybean and cottonseed) on ingestive behaviour, performance, carcass characteristics and meat quality

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1College of Veterinary Medicine and Animal Science, Universidade Federal de Mato Grosso do Sul – UFMS, Campo Grande, MS, Brasil
*Corresponding author: luis.itavo@ufms.br

of lambs finished in feedlot, in order to produce better quality meat and with greater benefits for consumer health.

2 Materials and method

The experiment was carried out at the College of Veterinary Medicine and Animal Sciences (FAMEZ), Federal University of Mato Grosso do Sul (UFMS) (Brazil). All procedures with animals were approved by Ethical Committee (protocol 654/2015).

Total of fifteen weaned non castrated Texel crossbred lambs (6 months-old, average weight 28.5 ± 1.65 kg) were used in the study. For parasite control, all lambs received a 2-ml intramuscular injection of antibiotic (Coccifin, Ouro Fino Saúde Animal, Ouro Fino, Cravinhos, SP, Brazil) to prevent coccidiosis. Lambs received also an anthelmintic treatment (sodic closantel 10 mg/kg BW; HIPRA, S.A., Amer (Girona), Spain) upon weaning. Lambs were housed in sheds made from clay tiles, with a ceiling height of 2.5 m and concrete paving, where they were randomly allotted into individual pens with 3 m2 (1.5 m × 2 m) each, with wood slat floor, water container and feed trough.

Whole corn silage was used as roughage feed at roughage:concentrate ratio of 400:600 (w/w) on DM basis. The amount of feed offered and refused were weighed daily and registered for each pen to determine DM intake. Treatments were composed of three diets (Table 1), the first dietary treatment was the control, composed of corn silage, milled corn, soybean meal and minerals, without addition of oilseeds. The two other dietary treatments had same composition of the control treatment, however, including either cottonseed or soybean.

The experimental basic diet (Table 1) was formulated to meet the National Research Council requirements for finishing lambs (National Research Council, 2007) with an average body weight of 30 kg, a potential gain of 250 g/day and estimated DM intake of 1 kg/day. The diets were formulated to be isonitrogenous (183 g/kg CP), and in the diets tests 50% of CP of the concentrate was replaced by oilseeds. Diet formulations with soybean grain and cottonseed reached 79 g/kg of EE.

The feed was offered twice a day (8:00 and 16:00) allowing nearly 50 g/kg of leftovers. Water was provided ad libitum. The evaluation of nutrient intake was determined from the 11th to the 14th day of each experimental period. The amount supplied and the leftover were weighed and sampled daily for determination of daily consumption. Animal samples were collected per period and the samples were submitted to chemical tests laboratory.

The samples of offered diet and leftovers were dried in a forced ventilation oven at 55 °C for 96 h and milled in the 1-mm mesh screen. The determinations of DM, organic matter (OM), crude protein (CP) level from total nitrogen and ethereal extract (EE), of the diets and the leftovers were performed according to AOAC International (Association of Official Analytical Chemists, 2000), methods 930.15, 942.05, 976.05, and 920.39, respectively. Heat stable α-amylase (Termamyl® 120; Sigma-Aldrich, St. Louis, MO, USA) was used to determine neutral detergent fibre (NDF) (Mertens, 2002) without sodium sulphite and was expressed inclusive of residual ash. Acid detergent fibre (ADF) was determined by Van Soest & Robertson (1985) method.

Trial had total of 56d of experimental period. With an adaptation period of 14d was respected prior to the 56d of total experimental period. In order to obtain average daily gain and body weight gain animals were initially weighed and weights were collected every 14d throughout the trial. Fasting period of 16 hours for solids was respected prior to weighing the animals. At the end of the experiment, animals were also fasted to be weighed and shipped to slaughter.

Total weight gain (TWG) was calculated according to the final weight (FW) minus initial weight (IW) and the average daily gain calculated based on TWG divided by the number of experimental days (56 days).

Ingestive behaviour observations were evaluated every 14 days with four observations performed throughout the day. Data collection was performed, on the 8th and 9th day of each experimental period, in sessions beginning at 8:00 a.m., at the first daily feeding, and continued for 48h. The number of meristic chews MMnc (number/bolus) was counted. To obtain the means of chewing, three ruminal bolus were observed in three different periods during the day (10:00 a.m. to 12:00 p.m., 2:00 p.m. to 4:00 p.m., and 6:00 p.m. to 8:00 p.m.). The calculations of meristic chews were obtained according to the methodology described by Meneses et al. (2014).

The collection of quantitative data on basic behavioural patterns was based on instantaneous scanning and continuous sampling. Therefore, 1-min scans were performed at 10-min intervals over the 48h observation period. A chronological framework was used to record the time lambs spent with water intake, feeding, ruminating, idling and chewing (Altmann, 1974; Martin & Bateson, 1993).

After 56 days, lambs were fasted for 16h before they were shipped to a commercial slaughterhouse. Lambs were slaughtered

Table 1. Chemical composition of total mixed diets.

	Treatments		
	Control	Soybean	Cottonseed
Corn silage	400.0	400.0	400.0
Corn meal	355.8	273.1	155.9
Soybean meal	234.2	101.2	120.8
Mineral premix*	10.0	10.0	10.0
Soybean grain	-	201.0	-
Cottonseed	-	-	313.3
Soybean oil	-	14.7	-
Dry matter (g/kg fresh matter)	679.3	675.6	669.0
Crude protein (g/kg dry matter)	183.1	183.1	183.1
Ether extract (g/kg dry matter)	32.3	79.0	79.0
NDF (g/kg dry matter)	186.7	196.9	260.0

NDF = neutral detergent fibre; *Mineral premix with Ca 70g/kg, P 48 g/kg, S 0.75 g/kg, Na 1.0 g/kg, Co 0.3 mg/kg, Cu 3.75 mg/kg, I 0.42 mg/kg, Mn 9.00 mg/kg, Se 0.12 mg/kg, Zn 27.0 mg/kg.

in a slaughter plant (Strut®) in Campo Grande, MS (Brazil). After concussion stunning with captive bolt pistol, using electro narcosis of 220 V for 10 sec., the carotid artery and jugular veins of the lambs were cut for blood drainage. Then carcass skinning and evisceration, decapitation and cut of the distal portion of the limbs were carried out. At the end of slaughter line, all carcasses were weighed to obtain hot carcass weight (HCW), which was used to calculate hot dressing (HD = HCW/SW × 100). After 24 h cooling at 4 ºC, all carcasses were weighed to obtain cold carcass weight (CCW) and cold dressing (CD = CCW/PA × 100).

The pH was measured in the Longissimus muscle after slaughter and after a 24-hour cooling period, measuring initial pH and final pH values. Objective evaluation of meat colour was performed on samples placed in plastic trays and exposed to the environment (18°C) for oxygenation for 20 min. After this period, the colour was determined by the average of three measurements taken at three different points of each sample with the aid of a portable spectrophotometer, model CM2500d (Konica Minuta Sensing Inc.), with light source D65, observation angle of 10º and opening of the 30 mm measuring cell. The L *, a *, b * scale of the CIELab system was adopted, where L * is the Chroma associated with luminosity (L * = 0 - black, 100 - white), a * is Chroma that varies from green (-) to red (+); and b *, which varies from blue (-) to yellow (+) (American Meat Science Association, 1995)

Before boning, the external length of the carcass was measured, measured between the base of the tail and the base of the neck. Internal and external carcass length, perimeter of the rump, and depth of the chest were determined on cold carcasses as described by Osório et al. (1996a, b). The internal length of the carcass, measured as the maximum distance between the anterior edge of the ischiopubic symphysis and the anterior edge of the first rib at its midpoint. The width of the rump was measured as the maximum width between the trochanters of both femurs, taken with compass. Perimeter of the croup, measurement of the outer surface of the croup, taking as reference the trochanters of both femurs. Depth of thorax, maximum distance between sternum and back of the carcass, taken with compass and width of thorax, perimeter of the widest region of the chest, taken with a tape (Cartaxo et al., 2009).

After the measurements were made, the carcass was subdivided into anatomical regions: Neck, obtained by means of an oblique cut between the seventh cervical vertebra and the first thoracic; Palette, region that has as its anatomical base the scapula; Ribs, anatomical basis in the last eight thoracic vertebrae along with upper half of the corresponding ribs; Loin, anatomical base in the six lumbar vertebrae, zone that perpendicularly strikes the spine, between the 13th thoracic vertebra and the lower lumbar region; Lamb rack, region that has as its bone base the first five dorsal vertebrae along with the upper half of the body of the corresponding ribs; and Gammon, gluteal, femoral and leg regions, having as base tarsus, tibia, femur, pubis and ileum, cut perpendicular to the spine, between the last two lumbar vertebrae. The sections were weighed individually and the percentages were determined in relation to the whole carcass (Macedo et al., 2008)

After boning, between the 12th and 13th rib of the Longissimus muscle, the transversal area of the loin eye area (LEA), measured in square centimetres, was taken on butter paper. The subcutaneous fat thickness (SFT) was evaluated on the left side of each carcass, at the same height of the muscle, with the aid of a caliper, and expressed in millimetres. A visual evaluation for fat amount and fat distribution in the carcass was made on a scale of 1 to 5, where 5 represents the excess and 1 the lack of fat.

Longissimus muscle samples were extracted and stored (2.5 cm thickness and -20 °C, respectively) for shear force analysis. Samples were conditioned in refrigerator for 24 hours at 4 °C for thawing process. Samples were baked until it reached an internal temperature of 72 °C. After cooling down samples reached 28 °C and were sectioned towards the muscle fibres having 1.23 cm in diameter. Shear force was determined by placing the samples in texturometer and analysed by the procedure "Warner-Bratzler Shear" (American Meat Science Association, 1995). Meat analyses were evaluated in natura (without pre-drying) for the variables DM, OM, NM, CP and EE, using the same food methodology.

Fatty acids in the Longissimus muscle were extracted and methylated using the adapted Hara & Radin (1978) method. The separation and identification of the fatty acid derivatives were carried out using a Trace GC Ultra Thermo gas chromatograph equipped with a flame ionization detector and a stationary phase capillary column consisting of 10% cyanopropylphenyl - 90% bis - cyanopropyl polysiloxane (Restek RTX - 2330, 105 mx 0.25 mm di x 0.20 µm). The following parameters were used to determine the fatty acids were: temperature detector of 270 °C and temperature injector of 250 °C. The method employed for temperature programming had initial column temperature of 120°C for 5 minutes. Then gradually raised at 3 °C/minute until the temperature reached 240 °C, remaining at that temperature for 15 minutes. The entrainment gas used was the helium with flow of 1.5 mL/min.

Parametric performance data and carcass and meat characteristics were subjected to variance analysis using SAS GLM procedure of SAS (SAS, 2008) according to the completely randomized design. Tukey test was performed to compare the means at 5% of significance level. However, for non-parametric data the Chi-square test was applied.

3 Results

The nutrient intake (DM, OM, CP, NDF, EE) was significantly (P = 0.0001) influenced by diet. The animals that received soybean grain treatment presented the highest DM intake (2049.4 g/day), consequently influencing CP, NDF and EE intakes. The animals that received cottonseed treatment presented the lower DM intake (1168.30 g/day) and the highest NDF intake (539.86 g/day) (Table 2).

There was a significant (P = 0.0001) effect of the diets for the final weight (FW), being the diet containing soybean grain (47.07 kg) greater than the diet containing cottonseed (42.54 kg) (Table 2). The mean total weight gain and daily gain of the animals that were fed the soybean diet (17.46 kg and 312 g/day, respectively) did not differ significantly from the control diet

Table 2. Nutrient intake, performance and behavioral activity of lambs fed oilseed in diet.

	Treatments			SE	P-value
	Control	Soybean	Cottonseed		
Nutrient Intake (g/day)					
Dry matter	1325.8[b]	2049.4[a]	1168.3[b]	85.57	0.0001
Organic matter	1268.9[a]	1227.5[a]	1109.70[b]	81.64	0.0001
Crude protein	229.2[b]	288.4[a]	219.55[b]	21.04	0.0001
NDF	431.8[b]	492.4[ab]	539.86[a]	38.07	0.0001
Ethereal extract	20.2[b]	58.7[a]	54.4[a]	2.46	0.0001
Productive performance					
Initial body weight (kg)	30.2	29.6	28.3	2.05	0.5379
Total weight gain (kg)	16.6[a]	17.5[a]	14.3[b]	0.66	0.0268
Final body weight (kg)	46.8[ab]	47.1[a]	42.5[b]	0.87	0.0001
Daily gain (g/day)	297.0[a]	312.0[a]	255.0[b]	11.80	0.0266
Ingestive behavior					
Idling (min/day)	588.0[a]	580.0[a]	465.0[b]	27.87	0.0001
Ruminating (min/day)	396.0[b]	402.0[b]	482.0[a]	18.43	0.0007
Water intake (min/day)	18.0	21.0	17.0	0.16	0.7611
Eating (min/day)	170.0[b]	201.0[a]	192[ab]	3.98	0.0492
Chewing (n/bolus)	74.0[b]	84.0[a]	80.0[ab]	0.57	0.0246

a-bMeans followed by different lower case letter differ by Tukey test ($P < 0.05$); NDF = neutral detergente fiber; SE = Standard error.

(16.62 kg and 297 g/day, respectively), and both were greater than the results from cottonseed diet (14.28 kg and 255 g/day, respectively, Table 2).

There was a significant (P = 0.0001) treatment effect for leisure activities, rumination (P = 0.0007) and feeding (P = 0.0492). The animals that received the cottonseed diet presented the highest rumination time (482 min/day) and the shortest leisure time (465 min/day) (Table 2). There was also a treatment effect (P = 0.0246) for the number of chews per cake. The treatment with soybean grain (84 cheeses/bolus) presented the highest mean and the control treatment had the lowest mean (74 chews/bolus) (Table 2).

The weight of hot and cold carcass was not affected by the diet, with averages of 22.66 kg and 21.57 kg between treatments. However, the cold carcass yield (CCY) presented treatment effect (P = 0.0001). The animals fed the control diet (47.99%) presented no difference when compared to the animals fed soybean diet (47.40%). However, both differed significantly (P = 0.0001) from the cottonseed diet (44.67%). Hot carcass yield was influenced by diet (P=0.0001), lambs fed the control diet showed higher yield (50.54%), not differing from soybean diet (49.28%), however, it was higher than the cotton diet (47.45%).

There was no treatment effect for the variables of initial pH and final pH of the carcass of the animals. After cooling, the pH drops also showed no significant difference (P = 0.8249). There was no treatment effect for SFT (P = 0.2341) and LEA (P = 0.8880). The internal and external length and depth of carcass did not differ (P > 0.05). Similarly, commercial cuts did not suffer from dietary effects (Table 3).

Regarding the qualitative characteristics of the carcass (Table 4), there was no significant effect on the body condition score (BCS) of the animals (P = 0.1780) averaging between 2.4 and 3.2. However, there was an effect on dressing of the animals (P = 0.0128). Animals that consumed the soybean (4.0) and control (3.6) diets had the highest mean values when compared to cottonseed (3.2) diet. There were no dietary effects on the carcass characteristics, such as marbling (3.0 points), maturity (2.9 points), fat texture (2.0 points) and muscle texture (1.5 points). There was an effect for the dressing measurement having the soybean grain treatment (4.0 points) greater than the cottonseed treatment (3.2 points).

There was no treatment effect for the shear force (4.3 kgf) and meat colour (Table 5). There was no treatment effect on DM, ash, and CP in meat of the animals submitted to the different diets. However, there was an effect (P = 0.0355) of the diet on the fat content in the meat. The meat of the animals that consumed cottonseed treatment had a lower fat content (26.3 g/kg), differing significantly from those who consumed soybean treatment (40.2 g/kg).

There was an effect of diets for fatty acids composition found in the lamb meat. Animals that were fed with cottonseed diet had lower values for saturated fatty acids and unsaturated fatty acids values when fed with the control and soybean treatment. In addition, meat of animals treated with soybeans showed greater amounts for both types of fatty acids when compared among treatments. However, their amount of unsaturated was higher than saturated (Table 5).

4 Discussion

The animals that received the soybean diet showed higher nutrient intakes when compared to the other treatments, also obtaining better performance results. However, the animals submitted to a cottonseed diet had a higher intake of NDF and lower consumption of DM and CP, resulting in a lower

Table 3. Carcass characteristics and commercial cut of lambs fed oilseed in diet.

	Treatments			SE	P-value
	Control	Soybean	Cottonseed		
Hot carcass weight (kg)	23.7	23.2	21.2	1.03	0.2952
Hot carcass yield (%)	50.5[a]	49.3[ab]	47.5[b]	0.65	0.0001
Cold carcass weight (kg)	22.5	22.3	20.0	1.02	0.2573
Cold carcass yield (%)	48.0[a]	47.4[a]	44.7[b]	0.59	0.0001
Housing initial pH	6.6	6.5	6.3	0.11	0.3073
Housing final pH	5.7	5.6	5.5	0.05	0.1750
pH drop	0.9	0.9	0.8	0.13	0.8249
Subcutaneous fat thickness (mm)	5.0	5.4	3.7	0.63	0.2341
Loin eye area (cm^2)	19.6	19.2	18.2	1.30	0.8880
Internal Length (cm)	62.4	62.0	61.5	1.43	0.9185
External Length (cm)	86.4	85.2	84.6	2.36	0.8873
Internal Depth (cm)	17.9	18.3	19.5	0.49	0.1528
External Depth (cm)	22.0	21.7	23.0	0.48	0.2319
Palette (kg)	4.5	4.5	4.0	0.36	0.1666
Gammon (kg)	7.1	7.1	6.5	0.37	0.3291
Rib (kg)	4.9	5.0	4.2	0.10	0.2040
Neck (kg)	1.7	1.4	1.4	0.33	0.2099
Loin (kg)	1.5	1.5	1.3	0.15	0.3180
Lamb Rack (kg)	2.5	2.6	3.4	0.34	0.6743

a-bMeans followed by different lower case letter differ by Tukey test ($P < 0.05$); SE = Standard error.

Table 4. Qualitative carcass characteristics [in points*] of lambs fed oilseed in diet.

	Treatments			SE	P-value
	Control	Soybean	Cottonseed		
Body condition score	3.2	2.8	2.4	0.17	0.1780
Marbling	3.6	3.0	2.4	0.28	0.2167
Maturity	3.2	3.0	2.6	0.25	0.6380
Finishing	3.6[ab]	4.0[a]	3.2[b]	0.12	0.0128
Fat texture	1.8	2.2	2.1	0.17	0.6240
Muscle texture	1.6	1.4	1.4	0.13	0.8040

a-bMeans followed by different lower case letter differ by Chi-square test ($P < 0.05$); *Scale of 1 to 5 points, where 5 represents the excess and 1 the lack of fat (AMSA, 1995); SE = Standard error.

performance when compared to animals exposed to other treatments. The performance results may be related to DM intake and nutrients intake because animals that had greater DM intake performed better than animals with lower DM intake.

The intake results of animals that received the cottonseed can be explained by the chemical composition of feed, where cottonseeds contain higher NDF than soybean, and the amount of NDF in cottonseed can be up to 3 times greater than in soybean, decreasing the digestibility of the diet (Cunha et al., 2008a). So, even the animals that consumed the diet containing cottonseed result in lower DM consumption, due to its high fibre value the NDF the consumption may still be higher. In addition, the intakes can be explained by the consumption habit of the animals, where the animals showed a fed selection during the experiment.

In contrast, Cunha et al. (2008a) working with different levels of cottonseed (0, 20, 30 and 40% of DM of the diet) for lambs in confinement did not find any change in dry matter consumption, where the amount of DM consumption with inclusion of 30% was similar to this work. Total and average daily weight gains decreased due to the increase in cottonseed inclusion; however, this reduction was relatively small, showing that the inclusion of cottonseed

The time spent with rumination is influenced by the nature of the diet (Cardoso et al., 2006), and NDF contents influence this parameter. A study conducted by Cardoso et al., (2006) evaluated the inclusion of 25%, 31%, 37% and 43% of NDF in the diet of Ile de France x Texel lambs, and found that as NDF levels of the diet increased, rumination time increased. The time spent with rumination is proportional to the cell wall content

Table 5. Characteristics and fatty acids profile of meat of lambs fed oilseed in diet.

	Treatments			SE	P-value
	Control	Soybean	Cottonseed		
Dry matter (g/kg fresh matter)	263.8	263.9	254.7	5.72	0.3753
Ash (g/kg DM)	59.9	57.9	51.4	3.55	0.1813
Crude protein (g/kg DM)	200.2	190.3	202.7	4.71	0.0592
Fat (g/kg DM)	36.9[ab]	40.2[a]	26.3[b]	4.31	0.0355
Total Unsaturated Fatty Acids (g/kg DM)	21.5[a]	22.3[a]	12.94[b]	2.36	0.0087
Total Saturated Fatty Acids (g/kg DM)	15.4[ab]	17.9[a]	13.36[b]	1.95	0.0474
Shear force (kgf)	3.7	4.8	4.4	0.46	0.1992
L	39.9	38.6	40.8	1.38	0.1992
a*	18.7	18.7	17.9	0.79	0.1992
b*	8.0	7.2	8.0	0.63	0.1992
Fatty acid profile (g/kg of fat)					
C10:0	0.95	0.8	1.0	0.11	0.0977
C12:0	0.62	0.5	0.6	0.12	0.4739
C14:0	15.56	14.9	16.2	2.38	0.1106
C15:0	1.54	1.5	2.3	0.22	0.4146
C16:0	232.2[ab]	217.2[a]	243.8[b]	28.16	0.0453
C16:1	12.8[a]	8.2[a]	7.2[b]	1.17	0.0007
C17:0	5.8	4.6	6.0	0.61	0.1042
C18:0	160.0[b]	206.2[a]	238.1[b]	30.57	0.0454
C18:1n9c	496.5[a]	428.2[a]	332.9[b]	51.33	0.0014
C18:2n6c	32.2[b]	54.5[a]	94.6[a]	5.34	0.0001
C20:4n	5.9[b]	5.8[ab]	11.7[a]	0.51	0.0050
CLA	36.0[b]	57.6[a]	45.6[b]	5.38	0.0002

a-bMeans followed by different lower case letter differ by Tukey test ($P < 0.05$); SE = Standard error; CLA = conjugated linoleic acid; DM = dry matter.

of food, thus, by increasing the level of NDF of the diet there is an increase in the time spent with rumination. Like this higher NDF consumption of the animals exposed to cottonseed diets also provided more time spent with rumination and less leisure time (Table 2). The concentration of NDF in the diet is considered an important factor due to its slow degradation and low passage rate through the rumen. It should be noted that the amount of inclusion of cottonseed in the diet was 313.3 g/kg of DM of the total diet. In contrast to this study, Rufino et al. (2015) found that the ingestive behaviour of confined lambs was not affected ($P> 0.05$) by the inclusion of cottonseed rations for leisure time, consuming ration, ruminating and drinking water.

The hot (47.45%) and cold (44.67%) carcass yields of the animals that received cottonseed were lower than in the other treatments. It can be explained by its lower performance when compared to other diets. Corroborating with these results, Cunha et al. (2008b) found that when the cottonseed was included in confined finishing sheep diet in 30% of DM, carcass yields were lower than the control treatment and similar to the values found in this study (HCY = 47.31 and CCY = 46.28).

The mean HCY of soybean (49.28%) treatment was similar to control and superior to cottonseed, due to its better performance. Similarly, Urano et al. (2006) found 48.8% DM when included 21% of soybean in the total diet. Also, Fernandes et al. (2011) in an experiment evaluating diets with soybean grain for lambs finished in confinement found an average of 49.40%. Likewise, Pinto et al. (2011) observed 49.4% to HCY of lambs fed diets with high fat.

As reported by Silva et al. (2005), who worked with animals from different genetic groups and observed a mean final pH of 5.6. When pH values are lower than 5.4 can favour the occurrence of PSE (pale, soft, exudative) meat, which in sheep in particular is rarely observed. Therefore, initial pH (6.45) and final pH (5.60) presented at this study can be considered within the range for sheep meat. The PSE condition provides less water retention capacity, also making the flesh flaccid and pale and compromising consumer acceptance. In contrast, final pH values above 6.0 cause browning (DFD - dark, firm, dry), increased water retention capacity and increased enzyme activity in the meat, decreasing shelf life. Evaluating the final pH results, values between 5.5 and 5.7 were observed, without effect of grain inclusion in the diet.

The SFT did not presents treatment effect ($P = 0.2341$). This result can be explained by the combination of the slaughter age of the animals (240 days) and the termination system. Fat is the component of the carcass that presents greater variation influenced mainly by the termination system.

The LEA measurements were similar between the treatments (P = 0.8880) and presented an average of 19 cm2. Urano et al. (2006) observed values of 14.8 cm2 in Santa Inês lamb fed with increasing levels of soybean grain and Cunha et al. (2008a) who worked with up to 40% inclusion of cottonseed in the diet of lambs and found LEA of 11.03 cm2. The greater results of this study when compared to the literature may be a consequence of the racial pattern of the animals (F1 Texel), termination system and the age of the animals.

There was no treatment effect on meat cuts. Commercial cuts may vary depending on genetics, gender, body weight, type of diet and number of hours of fasting (Yamamoto et al. 2004; Moreno et al. 2011). Fernandes et al. (2011) found similar results for the weights and yields of the main commercial cuts of the Santa Ines lambs finished in confinement. Additionally, Frescura et al. (2005) who tested different feeding systems at Ile de France × Texel finishing lambs also obtained averages of 33.31% for gammon, 19.17% for palette and 9.05% for neck. According to Cunha et al. (2008b) among the cuts considered noble, the gammon and loin presented, on average, 42.2% of income, a result similar to that found in this study (Table 4).

The treatment of soybean grain presented better dressing fat content, and the averages were between 4.0 points to the soybean grain treatment, 3.6 to the control treatment, and 3.2 points to the treatment with cottonseed. These values are similar to 3.66 points found by Homem Junior et al. (2010) who used diets with high EE for lambs in confinement. These results have been found because depending on the source of food and the genetics used can designate better dressing fat content (Teixeira & Borges, 2005).

The qualitative characteristics of the fat and muscle texture in the carcass did not present treatment effects reporting values of 1 to 3 points. Similarly, Lima et al. (2015) reported no difference in colour and texture of the meat from confined cattle fed diets varying from high and low lipid inclusion containing different fat sources. Likewise, Costa et al. (2013) working with cattle fed different inclusions of cottonseed in the diet found no significant differences in meat colour and texture.

There was no treatment effect for meat composition (DM, ASH, CP). However, there were significant values for the EE contents. The lambs' centesimal composition observed in this study is consistent with the values observed by Leão et al. (2011) for sheep meat, which can be considered lean meat since the values were below 5% fat. This fact is probably associated with the weight and age of the animal at slaughter. Likewise, Pereira et al. (2016) evaluated the nutritional quality of meat from lambs fed cotton by-product originated from biodiesel production and reported that the chemical composition and physicochemical characteristics were not influenced by levels of cotton by-product in the concentrate, observing total lipids in meat up to 3.2%.

The mean shear force was not affected by the diets (Table 5). However, these results considered as soft meat according to Bickerstaffe et al. (1997). In contrast, Silva et al. (2005) found differences between treatments of animals of different ages and genotypes at slaughter presenting shear force values above 7.0 kgf.

The lambs fed the control and soybean diet presented great amounts of saturated and unsaturated fatty acids, compared to diets containing cottonseed. These results could be explained by the amount of fat (g/kg DM) because cottonseed has low digestibility (Rico et al. 2017), which could be influencing the fatty acid absorption from cottonseed as lipid source. The meat of animals receiving the cottonseed diets had lower fat than the others treatments. In other words, the inclusion of these grains to raise the energy density of rations provided to the animals may improve performance and manipulate the quality of meat and carcass (Bassi et al., 2012). Corte et al. (2015) showed that the inclusion of cottonseed (10% and 20% DM) in the diet suggests that lambs may have satisfactory performance without negatively affecting carcass and meat quality.

Thus, our hypothesis that the lipid source should not impact the performance of male lambs is not supported by our data. However, the characteristics of the carcass, chemical and lipid composition of the meat are altered depending on the lipid source.

5 Conclusions

Diets containing oilseeds formulated to provide high levels of ethereal extract may be recommended to obtain satisfactory results in the production of lambs in feedlot. Meat of lambs treated with soybean has greater amounts for fatty acids mostly the unsaturated ones, beneficial to human health, and meat from lambs treated with cottonseeds has less fat.

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References

Altmann, J. (1974). Observational study of behavior sampling methods. Behaviour, 49(3), 227-267. http://dx.doi.org/10.1163/156853974X00534. PMid:4597405.

American Meat Science Association – AMSA. (1995). Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat. Chicago, Illinois: AMSA.

Association of Official Analytical Chemists – AOAC. (2000). Association of Official Analytical Communities (pp. 74-103). Arlington: AOAC.

Bassi, M. S., Ladeira, M. M., Chizzotti, M. L., Chizzotti, F. H. M., Oliveira, D. M., Machado, O. R. No., Carvalho, J. R. R., & Nogueira, Á. A. No. (2012). Grãos de oleaginosas na alimentação de novilhos zebuínos: consumo, digestibilidade e desempenho. Revista Brasileira de Zootecnia, 41(2), 353-359. http://dx.doi.org/10.1590/S1516-35982012000200018.

Bickerstaffe, R., Le Couteur, C. E., & Morton, J. D. (1997). Consistency of tenderness in New Zealand retail meat. In Proceedings of the 43th International Congress of Meat Science and Technology (pp. 196-197). Auckland, Nova Zelândia.

Cardoso, A. R., Carvalho, S., Galvani, D. B., Pires, C. C., Gasperin, B. G., & Garcia, R. P. A. (2006). Comportamento ingestivo de cordeiros alimentados com dietas contendo diferentes níveis de fibra em detergente neutro. Ciência Rural, 36(2), 604-609. http://dx.doi.org/10.1590/S0103-84782006000200038.

Cartaxo, F. Q., Cezar, M. F., Sousa, W. H., Gonzaga, S. No., Pereira, J. M. Fo., & Cunha, M. G. G. (2009). Características quantitativas da carcaça de cordeiros terminados em confinamento e abatidos em diferentes condições corporais. Revista Brasileira de Zootecnia, 38(4), 697-704. http://dx.doi.org/10.1590/S1516-35982009000400016.

Corte, R. R. P. S., Aferri, G., Pereira, A. S. C., Silva, S. L., Pesce, D. M. C., & Leme, P. R. (2015). Performance, carcass traits and meat quality of crossbred lambs fed whole cottonseed levels. Italian Journal of Animal Science, 14(4), 723-726. http://dx.doi.org/10.4081/ijas.2015.3685.

Costa, D. P. B., Roça, R. O., Costa, Q. P. B., Lanna, D. P. D., Lima, E. S., & Barros, W. M. (2013). Meat characteristics of Nellore steers fed whole cottonseed. Revista Brasileira de Zootecnia, 42(3), 183-192. http://dx.doi.org/10.1590/S1516-35982013000300006.

Cunha, M. G. G., Carvalho, F. F. R., Gonzaga, S. No., & Cezar, M. F. (2008a). 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. http://dx.doi.org/10.1590/S1516-35982008000600023.

Cunha, M. G. G., Carvalho, F. F. R., Véras, A. S. C., & Batista, Â. M. V. (2008b). Desempenho e digestibilidade aparente em ovinos confinados alimentados com dietas contendo níveis crescentes de caroço de algodão integral. Revista Brasileira de Zootecnia, 37(6), 1103-1111. http://dx.doi.org/10.1590/S1516-35982008000600022.

Fernandes, A. R. M., Orrico, M. A. P. Jr., Orrico, A. C. A., Vargas, F. M. Jr., & Oliveira, A. B. M. (2011). Desempenho e características qualitativas da carcaça e da carne de cordeiros terminados em confinamento alimentados com dietas contendo soja grão ou gordura protegida. Revista Brasileira de Zootecnia, 40(8), 1822-1829. http://dx.doi.org/10.1590/S1516-35982011000800028.

Frescura, R. B. M., Pires, C. C., Silva, J. H. S., Muller, L., Cardoso, A., Kippert, C. J., Peres, D. No., Silveira, C. D., Alebrante, L., & Thomas, L. (2005). Avaliação das proporções dos cortes da carcaça, características da carne e avaliação dos componentes do peso vivo de cordeiros. Revista Brasileira de Zootecnia, 34(1), 167-174. http://dx.doi.org/10.1590/S1516-35982005000100021.

Hara, A., & Radin, N. S. (1978). Lipid extraction of tissues with a low-toxicity solvent. Analytical Biochemistry, 90(1), 420-426. http://dx.doi.org/10.1016/0003-2697(78)90046-5. PMid:727482.

Homem Junior, A. C. Jr., Ezequiel, J. M. B., Galati, R. L., Gonçalves, J. S., Santos, V. C., & Sato, R. A. (2010). Grãos de girassol ou gordura protegida em dietas com alto concentrado e ganho compensatório de cordeiros em confinamento. Revista Brasileira de Zootecnia, 39(3), 563-571. http://dx.doi.org/10.1590/S1516-35982010000300016.

Leão, A. G., Silva, A. G. So., Moreno, G. M. B., Souza, H. B. A., Perez, H. L., & Loureiro, C. M. B. (2011). Nutritional characteristics of meat from lambs finished with diets containing sugar cane or corn silage on two levels of concentrate. Revista Brasileira de Zootecnia, 40(5), 1072-1079. http://dx.doi.org/10.1590/S1516-35982011000500019.

Lehninger, A. L., Nelson, D. L., & Cox, M. M. (2000). Princípios De Bioquímica. 2. Ed. São Paulo: Sarvier.

Lima, E. S., Morais, J. P. G., Roça, R. O., Costa, Q. P. B., Andrade, E. N., Vaz, V. P., Valente, T. N. P., & Costa, D. P. B. (2015). Meat Characteristics of Nellore cattle fed different levels of lipid-based diets. The Journal of Agricultural Science, 7(7), 174-183. http://dx.doi.org/10.5539/jas.v7n7p174.

Macedo, V. P., Garcia, C. A., Silveira, A. C., Monteiro, A. L. G., Macedo, F. A. F., & Spers, R. C. (2008). Composições tecidual e química do lombo de cordeiros alimentados com rações contendo semente de girassol em comedouros privativos. Revista Brasileira de Zootecnia, 37(10), 1860-1868. http://dx.doi.org/10.1590/S1516-35982008001000021.

Martin, P., & Bateson, R. (1993). Measuring behaviour (pp. 84-100). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139168342.

Meneses, M. D. A., Silva, F. F., Schio, A. R., Silva, R. R., Souza, D. D., & Porto, A. F. Jr. (2014). Feeding behavior of dairy cows in feedlot and fed on crude glycerin levels in the diet. Acta Scientiarum. Animal Sciences, 36(2), 171-176. http://dx.doi.org/10.4025/actascianimsci.v36i2.21488.

Mertens, D. R. (2002). Gravimetric determination of amylase-treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. Journal of AOAC International, 85(6), 1217-1240. PMid:12477183.

Moreno, G. M. B., Silva, A. G. So., Leão, A. G., Perez, H. L., Loureiro, C. M. B., & Pereira, G. T. (2011). Rendimento dos componentes não-carcaça de cordeiros alimentados com silagem de milho ou cana-de-açúcar e dois níveis de concentrado. Revista Brasileira de Zootecnia, 40(12), 2878-2885. http://dx.doi.org/10.1590/S1516-35982011001200035.

National Research Council – NRC. (2007). Nutrient requirement of small ruminants: sheep, goats, cervids and new world camelids (384 p.). Washington: National Academy Press.

Oliveira, D. M., Ladeira, M. M., Chizzotti, M. L., Machado, O. R. No., Ramos, E. M., Gonçalves, T. M., Bassi, M. S., Lanna, D. P. D., & Ribeiro, J. S. (2011). Fatty acid profile and qualitative characteristics of meat from Zebu steers fed with different oilseeds. Journal of Animal Science, 89(8), 2546-2555. http://dx.doi.org/10.2527/jas.2010-3553. PMid:21383038.

Osório, J. C., Oliveira, N. M., Jardim, P. O., & Monteiro, E. M. (1996a). Meat production in sheep of five genotypes. 2. Live weight components. Ciência Rural, 26, 471-475. http://dx.doi.org/10.1590/S0103-84781996000300023.

Osório, J. C., Oliveira, N. M., Nunes, A. P., & Pouey, J. L. (1996b). Meat production in sheep of five genotypes. 3. Losses and morphology. Ciência Rural, 26, 477-481. http://dx.doi.org/10.1590/S0103-84781996000300024.

Pereira, L., Pires, A. J. V., Carvalho, G. G. P., Silva, R. V. M. M., Simionato, J. I., Lacerda, E. C. Q., Bezerra, L. S., Eiras, C. E., & Carvalho, B. M. A. (2016). Nutritional characteristics of lambs meat fed diets with cotton cake. Journal of Food Quality, 39(2), 140-149. http://dx.doi.org/10.1111/jfq.12184.

Pinto, A. P. P., Furusho-Garcia, I. F., Leopoldino Júnior, I., Olalquiaga Pérez, J. R., Alves, N. G., & Pereira, I. G. (2011). Performance and carcass characteristics of lambs fed diets with fat and vitamin E. Revista Brasileira de Zootecnia, 40(12), 2911-2921. http://dx.doi.org/10.1590/S1516-35982011001200039.

Rico, J. E., de Souza, J., Allen, M. S., & Lock, A. L. (2017). Nutrient digestibility and milk production responses to increasing levels of palmitic acid supplementation vary in cows receiving diets with or without whole cottonseed. Journal of Animal Science, 95(1), 436-446. http://dx.doi.org/10.2527/JAS.2016.1089. PMid:28177348.

Rufino, J. Jr., Carvalho, D. M. G., Souza, J. G., Cabral, L. D. S., Silva, J. J., Ribeiro, M. D., Arnoldo, T. L. Q., Oliveira, A. S., & Soares, J. Q. (2015). Caroço de algodão em dietas sem volumoso para cordeiros confinados. Semina: Ciências Agrárias, 36(4), 2727-2738. http://dx.doi.org/10.5433/1679-0359.2015v36n4p2727.

SAS Institute Inc. - SAS. (2008). SAS/STAT 9.2 user's guide. Cary, NC: Statistical Analysis Systems Institute Inc.

Silva, A. G. So., Purchas, R. W., Kadim, I. T., & Yamamoto, S. M. (2005). Características de qualidade da carne de ovinos de diferentes genótipos e idades ao abate. Revista Brasileira de Zootecnia, 34(3), 1070-1078. http://dx.doi.org/10.1590/S1516-35982005000300040.

Teixeira, D. A. B., & Borges, I. (2005). Efeito do nível de caroço integral de algodão sobre o consumo e digestibilidade aparente da fração fibrosa do feno de braquíaria (Brachiaria decumbens) em ovinos. Arquivo Brasileiro de Medicina Veterinária e Zootecnia, 57(2), 229-233. http://dx.doi.org/10.1590/S0102-09352005000200015.

Urano, F. S., Pires, A. V., Susin, I., Mendes, C. Q., Rodrigues, G. H., Araujo, R. C., & Mattos, W. R. S. (2006). Desempenho e características da carcaça de cordeiros confinados alimentados com grãos de soja. Pesquisa Agropecuária Brasileira, 41(10), 1525-1530. http://dx.doi.org/10.1590/S0100-204X2006001000010.

Van Soest, P. J., & Robertson, J. B. (1985). Analysis of forages and fibrous foods - a laboratory manual for animal science. Ithaca, NY: Cornell University.

Yamamoto, S. M., Macedo, F. A. F., Mexia, A. A., Zundt, M., Sakaguti, E. S., Rocha, G. B. L., Regaçoni, K. C. T., & Macedo, R. M. G. (2004). Rendimentos dos cortes e não-componentes das carcaças de cordeiros terminados com dietas contendo diferentes fontes de óleo vegetal. Ciência Rural, 34(6), 1909-1913. http://dx.doi.org/10.1590/S0103-84782004000600037.