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Performance, gastrointestinal morphometry, carcass and non-carcass traits in sheep finished on diets containing canola (*Brassica napus* L.)

Mayara Mitiko Yoshiraha Carneiro[1], Rafael Henrique de Tonissi e Buschinelli de Goes[1*], Mayara Andressa Sabedot[1], Jefferson Rodrigues Gandra[2], Andrea Maria de Araujo Gabriel[1], Raquel Tenório de Oliveira[1], Nayara Gonçalves da Silva[1] and Douglas Gabriel Anschau[1]

[1]Faculdade de Ciências Agrárias, Universidade Federal da Grande Dourados, Rodovia Dourados-Itahum, Km 12, 79804-970, Dourados, Mato Grosso do Sul, Brazil. [2]Faculdade de Zootecnia, Universidade Federal do Sul e Sudeste do Pará, Xinguara, Pará, Brazil. *Author for correspondence. E-mail: rafaelgoes@ufgd.edu.br

ABSTRACT. The objective of this study was to evaluate performance, gastrointestinal morphometry, carcass, and non-carcass traits in lambs finished on different levels of canola grain in the diet. Twenty-seven Santa Ines lambs with an average initial weight of 19.33 ± 1.39 kg were given different levels of canola grain in the diet: 0, 8, and 16%. Weights and body condition scores were determined at the beginning, every 14 days and at the end of the experimental period. Animals were slaughtered to assess gastrointestinal morphometry, carcass and non-carcass traits. The statistical design used was completely randomized. The inclusion of canola grain showed a linear effect (0.723) for the width and height of ruminal papillae in the ventral region of the rumen. Intestinal villi and crypts showed a quadratic effect, with peaks of 0.62 μm and 0.43 μm, with the inclusion of 8 and 16%, respectively. When evaluating carcass traits, a decreasing linear effect was found for hot and cold carcass yield with 16% inclusion of canola. Canola grain can be used as an alternative in diets for finishing sheep up to 8% inclusion in the diet without affecting performance, ruminal and intestinal histometry, carcass, and non-carcass traits.

Keywords: conformation; lambs; crypts; oilseeds; papillae; villi.

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Introduction

The search for alternative ingredients in the diet for finishing sheep is essential to replace traditional feeds and reduce production costs. Canola (*Brassica napus* L. var. oleifera) is a protein and energy source, has ± 5,475 kcal kg^{-1} gross energy, ± 22.63% crude protein, and ± 6.32% crude fiber (Gopinger, Xavier, Silva, Dias, & Roll, 2015), and also stands out for being rich in unsaturated fatty acids, such as oleic (C18: 1), linoleic (C18: 2ω6), and linolenic acid (C18: 3ω3) (Wada et al., 2008), as well potential for use in animal feed, however it is still not widespread. Canola is the result of the genetic improvement of rapeseed (*Brassica napus* and *Brassica campestris*), with the purpose of reducing the content of erucic acid and glucosinolates to improve palatability and digestibility. The states of Rio Grande do Sul, Paraná and Mato Grosso do Sul, stand out as the largest national producers (Estevez, Duarte, Chambo, & Cruz, 2014).

When studying the introduction of new ingredients in the diet for lambs, it is important to evaluate the histometric aspects of the rumen and intestine, since the use of food happens in the gastrointestinal mucosa, as its epithelium has specificity for digestion, absorption and metabolic transport of nutrients, as well as, some physiological functions that correspond to the ruminal papillae and intestinal villi (Xu et al., 2009). In addition, rumen and intestine are considered an adaptive environment that changes according to the diet, the first undergoes changes in its epithelium particularly in the size of ruminal papillae, in adaptation to changes in ruminal parameters, such as pH, concentration of fatty acids and osmotic pressure. The second modifies the contact area in the lumen of the intestine according to the food ingested, adapting to meet the nutritional needs of the animal (Martens, Rabbani, Shen, Stumpff, & Deiner, 2012; Zitnan et al., 2008).

To maximize profits within a production unit, the ingredient used should demonstrate the action potential of the parameters that give value to the carcass in its yield, which is directly related to meat production, varying according to several factors inherent or not to the animal. It is worth mentioning the importance of measurements of carcass and non-carcass components, since the carcass, organs and viscera modify their structure according to the type of food the animal receives, allowing the prediction of characteristics that provide better product conformation, spreading its benefits to the entire production chain until the final consumer (Oliveira et al., 2014).

In view of the need to explore new ingredients for feeding sheep, the objective was to evaluate the inclusion of different levels of canola grain in the basal diet for finishing lambs and the relationship with ruminal and intestinal histometric parameters, performance, carcass and non-carcass traits.

Material and methods

The field experiment was carried out in the Sheep Farming Sector of the Experimental Station, in the Animal Nutrition Laboratory and Meat Technology Laboratory, School of Agricultural Sciences, Federal University of Grande Dourados, and at the Laboratory for the evaluation of oilseed by-products, at the Center of Research Laboratories in Agroenergy and Environmental Conservation (LAPAC/FINEP), municipality of Dourados, state of Mato Grosso do Sul, Brazil, between October and December 2012. This experiment was approved in accordance with the rules of the Ethics Committee on Animal Use, of this institution, number 021/2012 - CEUA/UFGD.

For the experiment, 27 Santa Ines lambs, with an initial body weight of 19.33 ± 1.39 kg were randomly and individually housed, identified and wormed according to egg counts per gram. Then, animals were subjected to 14 days of adaptation to the diet, management and facilities for later data collection.

The treatments consisted of three levels of inclusion of canola grain, on a dry matter basis (% DM): 0, 8, and 16%. Diet was weighed and supplied as complete feed, the mixture was made at the time of supply (silage + concentrate), individually *ad libitum*, in two daily meals (8:00am and 4:00pm), allowing 10% leftovers of the amount provided by the calculated margin of the previous day and water *ad libitum*. The source of forage used was corn silage and the concentrates were balanced according to NRC (2007) in order to be isoproteic (Table 1) to provide gains of 200 g day^{-1}. The forage: concentrate ratio was 10:90 in DM.

Table 1. Proportion of ingredients and chemical composition of experimental diets with levels of inclusion of canola grain at 0, 8, and 16% on a dry matter basis (% DM) supplied to finishing lambs.

Ingredients (%)	Levels of canola grain (%)		
	0	8	16
Corn silage	10.00	10.00	10.00
Corn grain	67.73	63.44	59.15
Soybean meal	20.27	16.56	12.85
Canola grain	0.00	8.00	16.00
Mineral mix[1]	2.00	2.00	2.00
Chemical composition (%)			
Dry matter	78.87	79.44	79.27
Crude protein	16.69	15.82	16.52
Ether extract	3.49	6.18	8.87
Neutral detergent fiber	42.26	34.10	42.88
Acid detergent fiber	10.75	12.51	11.56
Mineral matter	4.73	4.34	4.82
Total carbohydrates	75.09	73.66	69.79
Total digestible nutrients	66.87	71.53	66.51

[1]Mineral mix (nutrient per product kilogram): 80 g phosphorus; calcium 140 g; magnesium 7 g; sodium 133 g; 4,200 mg zinc; 300 mg copper; 800 mg manganese; 1,500 mg iron; 100 mg cobalt; 150 mg iodine; selenium 15 mg; fluorine (max) 800 mg.

The chemical composition of the ingredients (Table 1) was determined by the contents of dry matter (DM) method 967.03, mineral matter (MM) method 942.05, crude protein (CP) method 981.10, ether extract (EE) method 920.29, as described by AOAC, (1995).

For the analysis based on the determination of neutral detergent fiber (NDF) and acid detergent fiber (ADF), we used the methodology described by Van Soest, Robertson, and Lewis (1991), using 100 g m^{-2} non-woven bags (TNT) using the fiber determiner (TE-149 - Tecnal®), and adding heat-stable α-amylase, without sodium sulfite. The contents of Total Digestible Nutrients (TDN) were estimated according to NRC (2007) and for the determination of total carbohydrates (CHOT), we used the equation proposed by Sniffen, O'Connor, Van Soest, Fox, and Russell (1992).

The length of the experimental period, and the criterion for slaughtering animals, were defined by the time required to reach body condition three, on a scale of one to five, for standardization of the degree of carcass finishing, as described by Osório, Osório, Oliveira, and Siewerdt (2012). Lamb weight was determined at the beginning (initial body weight-BWi), every 14 days and at the end (final body weight (BWf) of the experimental period, determining the average daily gain (ADG). Body score was determined during animal weighing, by palpation of the lumbar region and insertion of the tail.

Dry matter intake (DMI) was obtained by the difference between the amount of DM offered and the amount of DM from leftovers. Feed conversion (FC) was calculated by the ratio of the average DMI (kg day^{-1}) and ADG (kg day^{-1}), while the feed efficiency (FE) was obtained by the inverse of this relationship.

Slaughtering was carried out after a solid fast for 16 hours, where the animals were sent stunned with electrical shock in the atlanto-occipital region, followed by bleeding with an incision in the carotid artery and jugular vein, skinning, and evisceration. Then, non-carcass components were separated and sequentially weighed, which consisted of blood, head, skin, paws, heart, liver, spleen, kidneys, lung with trachea, visceral fat, and full and empty gastrointestinal tract. After the described procedures, whole carcasses were weighed to calculate the hot carcass weight (HCW), used to determine the hot carcass yield (HCY) by calculating: HCW = CCW/WCA x 100; and transferred to a cold room at 4ºC for 24 hours, weighed to obtain the cold carcass weight (CCW), calculating the cold carcass yield (CCY) by calculating:

$$CCY = CCW \div WCA \times 100$$

In the chilled carcass, morphometry was evaluated according to Yañez et al. (2004) and after chilling, the croup width was measured according to the same authors, sequentially the carcasses were divided lengthwise and weighed.

In the left half carcass, measurements of the carcass external length, carcass internal length, thorax depth, leg length, total leg length and croup perimeter were taken, according to the methodologies described by Osório et al. (2012).

Carcass compactness index (cold carcass weight divided by the carcass internal length) and leg compactness (croup width divided by carcass length) were estimated according to Yañez et al. (2004).

Subsequently, the left half carcass was sectioned into five anatomical regions, neck, shoulder, rib, loin and leg, in the same way as Pinheiro, Silva-Sobrinho, Yamamoto, and Barbosa (2007), which were weighed to determine the weights (kg) and percentages (%) of the cuts in relation to the weight of the chilled half carcass.

The rib eye area (REA) was obtained by exposing the *Longissimus dorsi* muscle after a transversal cut in the carcass, between the 12th and 13th thoracic vertebrae, tracing its outline in acetate sheet and determining measure A (maximum muscle width) and measure B (maximum muscle depth) to estimate the rib eye area (REA) calculation using the formula (Osorio et al., 2012):

$$REA\ (cm^2) = (A \div 2\ \times B \div 2) \times \pi,$$

where: $\pi = 3.1416$.

After evisceration, organs of the gastrointestinal tract were identified and isolated, determining the pH of the rumen and abomasum. For microscopic examination, fragments of 3 cm^2 of the rumen were taken in the region of the dorsal and ventral sac, and in the small intestine, samples were taken after the pyloric region, in the central portion and in the portion close to the ileocecal junction. The sampled fragments were fixed in 10% buffered saline for 24 hours. Then they were washed in 70% alcohol to remove the fixative and then dehydrated for inclusion in paraffin to be sectioned in a microtome. Histological sections of five microtomes were stained with Hematoxylin/Eosin (Lomillos, Alonso, Ramiro, & Ramiro, 2017).

In rumen sections, height, width and area of the papillae and width of the muscular layer of the muscular tunic were measured and in the small intestine, villus height and crypt width (all in μm) were measured. Image capture and analysis were performed with the aid of computational software Q-Capture and ImagePro Express 6.0, coupled to a benchop microscope, with 4x and 10x objective lens, for the rumen and intestine sections, respectively.

The statistical design used was completely randomized (DIC), and slaughter weight was used in the model as a covariate. All statistical analyses were performed using PROC UNIVARIATE, PROC MIXED and PROC REG from the Statistical Analysis System, 9.2 (SAS, 2008), at 0.05 probability level. The statistical model used was:

$$Y_{ij} = \mu + \alpha_i\ +\ \varepsilon_{ij}$$

where: Yij represents the observation of canola level i in animal j, μ indicates the means of the dependent variables, α represents the fixed effect of canola grain i (i = 1, 2, 3), and εij represents the random error.

Results and discussion

There was no effect of inclusion levels of canola grain on the histometric parameters of the rumen and small intestine, pH of the rumen and abomasum of the lambs evaluated (Table 2). Ruminal pH values at slaughter remained within the range considered normal, which may imply a favorable environment for the establishment and growth of ruminal microorganisms, resulting in greater feed efficiency for ruminants.

Table 2. Mean and standard error of the mean of the histometric parameters evaluated in the rumen and small intestine, rumen pH and abomasum of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Rumen pH	6.64	6.86	6.77	0.25	0.54	0.76
Abomasum pH	2.84	3.41	3.09	0.78	0.76	0.65
Ventral Rumen						
Width (μm)	2.24	2.32	2.21	0.32	0.73	0.39
Height (μm)	9.03	8.07	9.81	1.45	0.63	0.03
Area (μm^2)	2511.15	3479.71	3320.62	0.78	0.02	0.82
Muscle layer (μm)	4.16	4.06	4.97	1.11	0.04	0.43
Dorsal Rumen						
Width (μm)	1.95	1.90	1.93	0.39	0.52	0.01
Height (μm)	4.89	3.81	5.72	1.55	0.62	0.02
Area (μm^2)	142612	87884	161182		0.82	0.03
Muscle layer (μm)	3.52	3.81	5.12	1.56	<0.00	0.76
Intestine						
Crypts (μm)	27.04	27.67	24.89	4.56	<0.00	0.43
Villi (μm)	171.4	177.07	145.71	44.73	<0.00	0.60

[1]SEM = standard error of the mean; [2]P-value = 5% probability of significance.

Muscle layers, both ventral (where the smaller food particles remain) and the dorsal one (where coarser particles remain, because of their density) showed the same increasing linear behavior, increasing as the inclusion of the grain was added, identifying a strengthening in the rumen muscle layer, and consequently, guaranteeing the correct functioning of the ruminal ecosystem by means of its motility, for separation of the smaller and larger particles, even with the inclusion of only 10% forage.

The gastrointestinal epithelium is responsible for some physiological functions, such as digestion and absorption that are related to the development of ruminal papillae (Xu et al., 2009). The inclusion of canola grain in lamb diet in up to 8% caused a linear and increasing quadratic effect for papilla area and height, respectively. However, as there was the inclusion of 16% canola grain, there were no differences ($p > 0.05$) in papillae area, however, their height showed a quadratic effect with a decrease in the ventral region of the rumen.

As for the dorsal region of the rumen, in view of the criteria adopted for width, height and area of ruminal papillae, they were presented in a quadratic form, having a smaller size when adding 8% canola grain in the diet, increasing its size with the inclusion at the level of 16%. Whereas, this region has an environment with coarse particles and that for this experiment where it was found higher content of ADF and lower content of NDF in the composition of the feed in 8% inclusion, thus proposing that the reduction in rumen papillae size may be related to the content of these nutrients (Table 1).

In view of the small intestine villi, a significant decreasing linear effect was found, verifying that the addition of canola grain in its increased levels in the diet demonstrates a decrease in the size of villi and crypts (Table 2). Intestinal microvilli are responsible for the absorption of nutrients and the greater their length, the greater the contact surface, thus having a greater absorption capacity. Intestinal crypts are responsible for the secretion of enzymes and defense cells (Cavalcanti et al., 2014). Thus, it can be observed that the inclusion of canola at 16% caused a reduction in the absorption capacity when included in the diet, as it caused a decrease in the size of intestinal villi. This may be linked to the yield of hot and cold carcasses (Table 4), which, when included at 16% canola grain, found losses in these yields, thus being able to work with the hypothesis that with a lower number of crypts and villi, inefficiency in enzyme secretions and decrease in villus size, with less absorption and consequently lower carcass yield.

The performance variables (Table 3) did not differ with levels of inclusion of canola grain, emphasizing the principle of normal distribution of samples in their initial body weight (Nóbrega et al., 2014).

Table 3. Mean and standard error of the mean of the performance variables of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Initial body weight (kg)	18.67	18.66	20.66	1.39	0.31	0.25
Daily weight gain (kg day^{-1})	0.13	0.17	0.17	0.01	0.28	0.39
Total weight gain (kg)	5.36	7.45	7.58	0.58	0.31	0.29
Dry matter intake (kg day^{-1})	0.82	1.08	1.03	0.07	0.23	0.36
Dry matter intake (% BW[3])	3.95	4.87	4.56	0.16	0.18	0.25
DM intake (kg $BW^{-0.75}$)	0.08	0.11	0.10	0.00	0.25	0.21
Food conversion	7.78	6.54	6.27	0.72	0.36	0.34
Feed efficiency	0.16	0.17	0.17	0.01	0.21	0.21

[1]SEM = standard error of the mean. [2]P = 5% probability of significance. [3]BW = Body weight.

Dry matter intake (DMI) may decrease when adding lipid sources to the diet of more than 7%, possibly due to the greater difficulty of attachment of fibrolytic bacteria to fibers of food origin. Although the 16% canola grain diet showed 8.87% EE, it did not affect the lamb DMI.

For carcass traits, there was a linear effect ($p < 0.05$) only for hot (HCY) and cold (CCY) carcass yield (Table 4) with reduced yield as the levels of canola grain increased.

Table 4. Mean and standard error of the mean of carcass traits of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Final body weight (kg)	24.82	27.25	27.31	1.60	0.31	0.25
Slaughter weight (kg)	24.03	26.11	26.24	1.50	0.32	0.32
Fasting loss (%)	3.11	4.02	3.82	0.42	0.23	0.36
Hot carcass weight (kg)	11.51	12.30	11.66	0.72	0.48	0.27
Cold carcass weight (kg)	10.74	11.75	11.09	0.69	0.47	0.30
Hot carcass yield (%)	47.58[a]	47.26[a]	44.08[b]	0.61	0.01[3]	0.02
Cold carcass yield (%)	44.47[a]	45.10[a]	41.87[b]	0.54	0.03[4]	0.04
Chilling loss (%)	6.47	4.58	5.03	0.34	0.16	0.20

[1]SEM = standard error of the mean. P = 5% probability of significance. [3]$Y = 50.1297 - 1.87429X$ ($r^2 = 0.38$); [4]$Y = 46.8501 - 1.46895X$ ($r^2 = 0.29$). Mean values followed by different lowercase letters in the same row are significantly different by Tukey's test at 5% probability.

Despite the reduction in HCY and CCY, the values were within the normal range for sheep for meat production, between 40 and 50%. Santos, Ezequiel, Pinheiro, Barbosa, and Galati (2009) tested the inclusion at 8% canola grain in lamb diets and found HCW and CCY of 45.62% and 46.12%, respectively.

Chilling loss index expresses the difference in weight after carcass cooling, being mainly influenced by the amount of cover fat (Cunha, Carvalho, Gonzaga Neto, & Cezar, 2008), the values found in this research corroborate the data evidenced by Martins, Oliveira, Osório, and Osório (2012), indicating that the variation may occur between 1 and 7% in sheep.

In a study with lambs fed canola grain, Asadollahi, Sari, Erafanimajd, Kiane, and Ponnampalam (2017) observed a large number of grains in feces of lambs and found that the membrane surrounding canola grains are resistant to rupture, which reduces digestibility, and may cause less absorption of the grain, which works as a by-pass.

Despite the decreasing linear effect of the use of canola grain on hot and cold carcass yield, the weights and yields of commercial cuts were not influenced (Table 4), which may be related to the low correlation coefficient ($r = 0.29$) in regression analysis when considering the inclusion of canola in relation to the variables analyzed. However, with uniformity of the slaughtered animals, these characteristics are important for commercial cuts.

The subjective characteristics (Table 5) were not affected by the diet, remaining unchanged under the linear and quadratic effect of the regression analysis.

Table 5. Mean and standard error of the mean of the subjective carcass traits of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Texture	2.50	2.67	2.83	0.07	0.09	0.25
Marbling	1.75	1.58	1.58	0.09	0.27	0.35
Greasiness	2.63	2.75	2.92	0.07	0.14	0.36
Color	2.75	2.83	2.50	0.17	0.27	0.29
Conformation	2.63	2.75	3.00	0.11	0.18	0.39

[1]SEM = standard error of the mean. [2]P = 5% probability of significance.

Osório et al. (2012) explain that the link for understanding between what the consumer wants from fat and what the producer can achieve, is expressed through the covering of fat in the carcass. The animals in this study were slaughtered with a similar body condition score (3.0), which caused uniformity in the carcasses and in greasy state. Nevertheless, it is worth mentioning that although not significant, a minimum fat cover is desirable to protect the carcass, avoiding water loss and burns caused by the cooling and freezing process, considering the values presented in the study, positive from the operational point of view (Santos et al., 2009).

Biometric measurements (Table 6) of the carcasses and characteristics of the rib eye area (REA) were not influenced by the levels of canola grain in the diet, corroborating the data by Marques et al. (2007), who stated that the morphometric measures are poorly influenced by nutritional management, as long as the animals are slaughtered with similar weights.

Table 6. Mean and standard error of the mean of the carcass biometrics and characteristics of the *Longissimus dorsi* muscle of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
External carcass length (cm)	51.12	52.90	52.18	0.97	0.38	0.31
Internal carcass length (cm)	57.91	59.36	58.37	1.09	0.47	0.34
Leg length (cm)	21.13	20.10	19.14	0.70	0.23	0.27
Total leg length (cm)	35.43	34.59	34.79	0.50	0.13	0.37
Thorax depth (cm)	23.88	22.29	22.62	0.52	0.20	0.20
Croup perimeter (cm)	54.56	54.29	54.17	1.40	0.44	0.16
Croup width (cm)	19.72	19.84	19.77	0.53	0.50	0.27
Small intestine length (cm)	23.97	24.87	24.67	0.48	0.33	0.37
Carcass compactness (kg cm^{-1})	0.19	0.20	0.19	0.01	0.46	0.30
Leg compactness (kg cm^{-1})	0.56	0.58	0.57	0.01	0.44	0.39
Maximum width A (cm)	5.32	5.10	4.91	0.13	0.23	0.36
Maximum depth B (cm)	2.99	2.71	2.63	0.10	0.18	0.31
Minimum fat thickness (mm)	0.52	0.65	0.58	0.05	0.33	0.32
Maximum fat thickness (mm)	2.86	2.74	2.83	0.27	0.48	0.34
Rib eye area (cm^2)	12.61	10.82	10.27	0.06	0.15	0.21

[1]SEM = standard error of the mean; [2]p = 5% probability of significance.

The lack of effect on slaughter weight and the slaughter weight range explains the similarity in carcass traits, as well as in fat deposition, since the weight range for finding suitable fat depositions in Santa Ines sheep is between 15 and 35 kg body weight. Above these, adipose tissue shows positive heterogeneous growth, with marked deposition (Fernandes Júnior et al., 2015).

The lack of effect on the mean values of meat compactness index in the carcass and leg allows observing the homogeneity in the storage capacity of tissues in commercial cuts (Table 7) (Ítavo et al., 2009).

The different cuts that make up the sheep carcass have different economic values and their proportion is an important index for assessing the commercial quality of carcasses. The cuts considered noble (ham and loin) totaled 46.61% together (Table 7), which shows a good yield, since they are the most commercially valued cuts, the expected of a good carcass is that it has the maximum yield of these cuts.

The weights of non-carcass components were not influenced by canola grain in the diet (Table 8).

According to Andrade et al. (2009), the development of non-carcass components usually accompanies the animal weight, therefore, animals with similar slaughter weights explain the lack of effect on the characteristics of non-carcass components of animals fed different levels of canola grain.

Organs and viscera have different growth rates during the animal life, when compared to other parts of the body and may be related to the chemical composition of food, especially the energy content (Pompeu et al., 2013). This may have contributed to the lack of effect on the weight of non-carcass components, since the energy content of the diets in this study was similar (Table 1).

Table 7. Mean and standard error of the mean weight (kg) and yield (%) of the cuts of the left half carcass of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			EPM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Neck (kg)	0.33	0.38	0.33	0.03	0.47	0.32
Neck (%)	5.14	5.52	4.83	0.31	0.49	0.45
Shoulder (kg)	1.02	1.11	1.01	0.06	0.42	0.32
Shoulder (%)	16.36	16.58	15.69	0.28	0.35	0.11
Leg (kg)	1.94	2.04	1.89	0.11	0.41	0.19
Leg (%)	31.06	30.41	29.08	0.46	0.30	0.16
Loin (kg)	0.99	1.10	1.09	0.06	0.31	0.28
Loin (%)	16.06	16.52	16.70	0.26	0.26	0.38
Rib (kg)	1.94	2.08	2.22	0.14	0.24	0.17
Rib (%)	31.38	30.98	33.70	0.58	0.08	0.15

[1]SEM = standard error of the mean; [2]p = 5% probability of significance.

Table 8. Mean and standard error of the mean weight of non-carcass components of lambs finished with 0, 8, and 16% inclusion of canola grain in the diet.

Variables	Inclusion levels (%)			SEM[1]	P-value[2]	
	0	8	16		Linear	Quadratic
Blood (kg)	1.11	1.11	1.08	0.06	0.41	0.33
Skin (kg)	2.25	2.53	2.79	0.15	0.19	0.36
Paws (kg)	0.63	0.66	0.65	0.02	0.40	0.30
Head (kg)	1.00	1.04	1.06	0.04	0.31	0.64
Heart (kg)	0.13	0.13	0.13	0.00	0.35	0.17
Kidneys (kg)	0.12	0.08	0.09	0.00	0.18	0.27
Liver (kg)	0.48	0.56	0.56	0.03	0.25	0.24
Spleen (kg)	0.06	0.06	0.06	0.00	0.37	0.23
Renal fat (kg)	0.13	0.20	0.23	0.03	0.20	0.36
Tongue (kg)	0.06	0.08	0.06	0.04	0.33	0.47
Full GTI[3] (kg)	5.90	6.61	6.95	0.47	0.22	0.70
Empty GTI (kg)	2.27	2.72	2.65	0.17	0.25	0.26
Reproductive system (kg)	0.03	0.05	0.06	0.00	0.11	0.26
Lung + Trachea (kg)	0.60	0.62	0.65	0.04	0.32	0.55

[1]SEM = standard error of the mean; [2]p = 5% probability of significance; [3] Gastrointestinal tract.

Conclusion

Inclusion of canola grain in the diet for finishing sheep can be made in up to 8% without affecting the performance and traits of carcass and non-carcass components, therefore it is a potential alternative substitute to conventional protein and energy grains.

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