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ANIMAL PRODUCTION

Intake, digestibility, performance and carcass characteristics of ewes fed crambe replacing soybean meal in the diet

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ABSTRACT. The use of alternative sources of protein for ruminant can alter productivity and reduce costs in animal production. The aim of this study was to evaluate the performance, apparent digestibility and quantitative characteristics of carcass components of ewes fed increasing levels (0, 50, 100 and 150 g kg^{-1} dry matter) of crambe crushed in the diets. Twenty-four culling ewes were distributed in a completely randomized design. All animals were kept in a shed, with individual stalls equipped with feeder, drinker and concrete floor covered with rice hulls. The animals received corn silage as roughage and diets were isoenergetic with 700 g kg^{-1} of TDN. Animals were slaughtered when reached a body condition score of 3.5 points. The dry matter intake (948.53 g day^{-1}) and average daily gain (0.15 kg day^{-1}) were not influenced by the inclusion of crambe crushed in the diet. The crambe crushed increased ether extract digestibility and decreased crude protein intake and digestibility. There was no effect of the levels of crambe crushed on carcass characteristics and non-carcass components but rather a reduction in the cold carcass yield. Total replacement of soybean meal with crambe crushed in the diet for ewes did not alter performance, carcass and non-carcass characteristics.

Keywords: byproduct; ether extract; oilseeds; *Crambe abyssinica*.

Consumo, digestibilidade, desempenho e características de carcaça de ovelhas alimentadas com crambe em substituição à farelo de soja

RESUMO. O uso de fontes proteicas alternativas para ruminantes pode alterar a produtividade e reduzir os custos na produção animal. O objetivo da pesquisa foi avaliar o desempenho, a digestibilidade aparente e as características quantitativas dos componentes de carcaça das ovelhas alimentadas com níveis crescentes (0, 50, 100 e 150 g kg^{-1} de matéria seca) de torta de crambe nas dietas. Foram distribuídas 24 ovelhas em um delineamento inteiramente casualizado. Todos os animais foram mantidos em instalação, com baias individuais equipadas com cocho, bebedouro e chão de concreto coberto com cascas de arroz. Os animais receberam silagem de milho como forragem e as dietas foram isoenergéticas com 700 g kg^{-1} de NDT. Os animais foram abatidos quando atingiram o escore de condição corporal de 3,5 pontos. A ingestão de matéria seca (948,53 g dia^{-1}) e o ganho médio diário (0,15 kg dia^{-1}) não foram influenciados pela inclusão de torta de crambe na dieta. A torta de crambe aumentou a digestibilidade do extrato etéreo e diminuiu a ingestão e digestibilidade da proteína bruta. Não houve efeito da torta de crambe nas características da carcaça e nos componentes não carcaça, no entanto houve redução no rendimento da carcaça fria. A substituição total da farinha de soja e a torta de crambe na dieta para as ovelhas não alteraram as características de desempenho, carcaça e não carcaça.

Palavras-chave: subproduto; extrato etéreo; oleaginosas; *Crambe abyssinica*.

Introduction

A large amount of agriculture and agribusiness co-products has potential for use in animal feeding and might be used as sources of nutrients for animals. Soybean is the major raw material for vegetable oil production, which accounts for over 800 g kg^{-1} of the biodiesel produced and represents a major source of protein in animal nutrition. However, the rising cost of feed has increased the cost of production and reduced the profit margin for producers (Rodrigues et al., 2013). In this sense, there is a growing research for new oilseeds, which produce oil for biodiesel production within the international quality standards (Roscoe, Richetti, &

Maranho, 2007), among which, stands out the crambe (*Crambe abyssinica* Hoeschst).

Crambe is an alternative winter crop, resistant to low temperatures and might be used in the soybean off-season. Co-products (crambe meal and crambe crushed) have desirable characteristics for use as ruminant feed, in order to contribute to the intensification of production chain.

Crambe crushed, from the mechanical cold pressing for oil extraction, consists of the pericarp, rich in fiber, and cotyledons, which are rich in protein and residual oil, and the use of these provides the organic matter reuse of vegetable origin (Mizubuti et al., 2011).

The crambe crushed can replace conventional protein sources used in ruminant nutrition, such as soybean meal, reducing feeding costs. In accordance with Syperreck et al. (2016), the use of 700 g kg^{-1} crambe crushed in sheep diets, improves intake, decreases feeding and rumination time and can lead to sustainable and cost-effective lamb production.

Thus, there is a fundamental importance to study basic principles about feeds, characteristics and chemical composition, to formulate balanced diets to meet the requirements of animals, exploring the maximum digestive capacity, managing to reach its genetic potential for use of dietary energy consumed.

Ítavo et al. (2016) observed effects on dry matter (DM), crude protein (CP) and neutral detergent fiber (NDF) intakes, but no effects on their digestibility when lambs were fed with different levels (0; 64,128 and 192 g kg^{-1} DM) of crambe meal in the diet.

In studies on alternative feed, carcass composition is a very important point to be considered, since it is associated with the carcass yield, meat quality and hence the economic return of the activity; allowing comparisons between breeds, weight and slaughter weight, feeding system, and the correlations with other measures or carcass tissue components (Pinheiro, Jorge, & Yokoo, 2010).

Souza, Goes, Silva, Yoshihara, and Prado (2015) evaluated animal performance and carcass characteristics of culling cows fed diets containing crambe crushed replacing soybean meal at 0; 50; 100 and 150 g kg^{-1} DM in concentrate supplements and observed no effect on the performance and the characteristics of animal carcasses finished on pasture.

However, Ítavo et al. (2016) observed a linear decreasing effect on subcutaneous fat thickness of lamb carcasses feeding crambe meal in the diet.

This study was realized to evaluate the performance, apparent digestibility of nutrients and quantitative characteristics of carcass and non-carcass components of ewes fed crambe crushed replacing soybean meal in the diet.

Material and methods

The experiment was conducted at the Sheep Production Facilities of the Experimental Station and Laboratory of Animal Nutrition and Meat Technology Laboratory of Federal University of Dourados/UFGD – MS. This experiment was conducted in accordance with guidelines of the Ethics Committee on Animal Use of this institution, under opinion number 021/2012 – CEUA – UFGD.

Santa Ines x Suffolk crossbred ewes (n = 28), with 30 months of age were randomly distributed into four levels of crambe crushed (0; 50; 100 and 150 g kg^{-1} DM) in the total mixed diet. Diets (Tables 1 and 2) were formulated according to National Research Council (NRC, 2007) to be isonitrogenous (150 g kg^{-1}) and isoenergetic with 700 g kg^{-1} total digestible nutrients (TDN), gain weight around 250 g day^{-1}; and an estimated dry matter intake of 1 kg day^{-1}. The daily intake was *ad libitum*, at 08h00 and 16h00. Corn silage was used as roughage at forage-concentrate ratio of 150:850 on a DM basis. Amounts offered and refused were weighed daily to determine feed intake. Feed consumption was adjusted for 100 g kg^{-1} of orts and water supplied was also *ad libitum*.

Table 1. Chemical composition of ingredients used in the experimental diets.

Ingredients (g kg^{-1} DM)*	DM	CP	EE	NDF	ADF	MM
Crambe crushed	923.4	286.5	188.4	549.8	243.5	57.8
Soybean meal	892.1	485.1	17.8	149.0	70.0	72.3
Corn	877.0	105.7	31.9	182.1	43.7	16.7
Corn silage	287.3	59.6	26.1	446.4	245.3	541

*DM = dry matter, CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber, MM = mineral matter.

TDN content of concentrated feed, corn silage and orts were estimated according to equations proposed by Cappelle, Valadares Filho, Silva and Cecon (2001): $TDN = 91.0246 - 0.571588 * NDF$; $TDN = 74.49 - 0.5635 * ADF$ and, $TDN = 3.71095 - 0.129014 * NDF + 1.02278 * OMD$; based on neutral detergent fiber (NDF), acid detergent fiber (ADF) and organic matter digestibility (OMD). For total carbohydrates (TC), we used the equation: $TC = 100 - (g\,kg - 1\,CP + g\,kg - 1\,EE\% + g\,kg - 1\,MM)$, as described by Sniffen, O'Connor, Van Soest, Fox and Russell (1992). And the content of non-fiber carbohydrates (NFC) was obtained using the equation: $CNF = TC - NDF$.

All animals were kept in a shed, with individual stalls equipped with feeder, drinker and concrete floor covered with rice hulls, and were subjected to a period of adaptation to facilities, management and experimental diet for 14 days. Ewes were weighed and monitored according to the body condition score at the end of each experimental period consisting of 14 days. The eggs count per gram of feces (EPG) was conducted, and whenever necessary, animals were dewormed.

Table 2. Concentrates and chemical compositions of experimental diets fed to ewes.

	g kg^{-1} dry matter crambe crushed			
	0	50	100	150
Corn silage	150.0	150.0	150.0	150.0
Corn grain	659.1	666.2	673.3	668.5
Soybean meal	150.0	100.0	50.0	00.0
Crambe crushed	00.0	50.0	100.0	150.0
Urea	05.0	05.0	0.5.0	05.0
Dicalcium phosphate	18.3	17.3	16.3	15.3
Mineral mixture[1]	17.6	11.5	05.4	11.2
Chemical composition (g kg^{-1} DM)				
Dry matter	700.1	701.9	700.5	720.8
Crude protein	149.3	150.0	149.1	148.8
Ether extract	17.1	21.1	23.6	41.2
Neutral detergent fiber	294.1	307.0	295.9	294.2
Acid detergent fiber	100.0	111.1	105.6	113.2
Mineral matter	49.6	50.2	48.7	69.8
Lignin	25.9	27.8	30.9	34.9
Non-fiber carbohydrates	489.9	468.7	504.7	469.7
Total carbohydrates	784.0	775.7	800.6	763.9
TDN	742.2	734.8	741.1	742.1

[1]Mineral Supplement (nutrients per kilogram of product): 80g phosphorus; 140g calcium; 7g magnesium; 12g sulfur; 133g sodium; 4,200 mg zinc; 300 mg copper; 800 mg manganese; 1,500 mg iron; 100 mg cobalt; 150 mg iodine; 15 mg selenium; 800 mg fluoride (max); 2% citric acid soluble phosphorus (min) 95%.

Feces were collected on the 12nd, 13rd and 14th days of each experimental period at the same time of meals (08h00 and 16h00). The diet offered, orts and feces were weighed and recorded daily, and then combined to form composite samples per animal/ treatment/ period. Samples of the diets, orts and feces were packed in plastic bags and stored in a freezer at -20°C for subsequent analysis to determine nutrient intake and the coefficient of digestibility of nutrients. Samples were thawed at room temperature, followed by pre-drying in a forced ventilation oven at 55°C for 72h, and ground in a Wiley mill with 1 mm sieve for determination of dry matter (DM – method 930.15); ash (method 942.05) and organic matter ($OM = 100 - ash$); crude protein (CP – method 976.05, N * 6.25) and ether extract (EE – method 920.39), following the methodologies of Association of Official Analytical Chemist (AOAC, 2005). ADF contents were obtained following method described by Van Soest, Robertson and Lewis (1991). Lignin content was obtained by oxidation with potassium permanganate (Van Soest & Wine, 1968). For NDF analysis, samples were treated with heat stable alpha amylase without sodium sulfite and corrected for ash residue (Mertens, 2002).

Dry matter intake (DMI) was calculated by the relationship between the DM offered and the DM orts: $DMI = (DM_{diet} * amount\ supplied) - (DM_{orts} * amount\ of\ orts)$ as well as the nutrient intake (NI) by means of relationships with the DM and their content in the diet ingested and in the orts: $NI = [g\ kg^{-1}\ \text{nutrient}_{DM\ diet} * DM_{ingested}] - [g\ kg^{-1}\ nutrient_{DM\ orst} * DM_{orst}]$.

To estimate the fecal dry matter production, the indigestible acid detergent fiber (iADF) was used as an internal indicator. Samples of feed, feces and orts were incubated directly in the rumen of a steer with approximately 450 kg body weight for 240 hours, 0.5 g samples were incubated in bags of TNT (100 g m^{-2}) with 5 x 5 cm size, as recommended by Casali et al. (2008), respecting the ratio 20 mg cm^{-2}. Bags were sealed, placed into tulle bags, measuring 15 x 30 cm, with a small lead weight of 100 g. The bag was tied to a nylon thread approximately 0.5 m length. Material remaining from incubation was washed in tap water and dried in a forced ventilation oven at 55°C for 72 hours and subjected to extraction with acid detergent (Casali et al., 2008).

The estimation of Fecal DM was obtained by the following formula:

$$Fecal\ DM\ (g\ day^{-1}) = \left(\frac{ingested\ marker\ (g)}{markes\ concentration\ in\ feces}\right).$$

The DM total digestibility coefficient (DMD) was obtained by the difference between the amount of dry matter ingested and fecal DM:

$$DMD = 100 * \left(\frac{(DM\ intake - Fecal\ DM)}{DM\ intake}\right).$$

The nutrient total digestibility coefficient (tND) was calculated by the relationship with DM, the content in the diet, the orts and fecal output:

$$tND = \left(\frac{\left((DM\ intake * g\ kg^{-1}) - (DM\ excreted * gkg^{-1})\right) * 100}{(DM\ ingested * g\ kg^{-1}\ nutriente)}\right).$$

Animals were slaughtered based on individual body score, with scores assigned on a scale of 1-5, in which 1 = excessively lean and 5 = excessively fat, to standardize the fattening state of the carcasses. The body condition of all animals, established as indicative of the slaughter time was 3.0 to 3.5 (Osório et al., 1998).

After 60 days, ewes were fasted for 16 hours before slaughter and weighed to obtain slaughter weight (SW). All animals were stunned using electrical discharge (220V for 10 s) in the atlanto-occipital region, followed by bleeding with an incision in the carotid artery and jugular vein, skinning and gutting. Then, non-carcass components were separated and weighed, namely, blood, head skin, legs, heart, liver, spleen, kidneys, lungs with trachea, fat, visceral and full and empty gastrointestinal tract.

Later, the carcasses were weighed to calculate the hot carcass weight (HCW), used to determine the hot carcass yield (HCY), and transferred to a chilling room at 4°C for 24 hours, and weighed to obtain the cold carcass weight (CCW), calculating the cold carcass yield (CCY).

After chilling, carcasses were cut lengthwise, and in the left half carcass, the following measurements were taken: carcass external length, carcass internal length, depth of chest, rump width, leg length, total length of the leg, rump perimeter, in accordance with the methods described by Osório et al. (1998). In sequence, it was calculated the carcass compactness index (CCI) (cold carcass weight divided by the carcass internal length) and leg compactness index (LCI) (rump width divided by the length of the leg). Then, the carcass was divided into five anatomical regions: neck, shoulder, rib, loin and leg, which were weighed to determine the weights (kg) and percentages (g kg^{-1}) of cuts in relation to cold carcass weight.

Measurements of loin eye area (LEA) and subcutaneous fat thickness were taken in the *Longissimus* muscle between the 12^{nd} and 13^{rd} thoracic vertebrae, using a thin plastic sheet, determining measure A (maximum muscle width) and measure B (maximum muscle depth) to estimate the loin eye area (LEA) using the formula: $LEA\ (cm^2) = \left(\frac{A}{2} * \frac{B}{2}\right) * \pi$, where: $\pi = 3.1416$, and the subcutaneous fat thickness (SFT) was determined in the fat layer where LEA was determined, measured at three points with a caliper, obtaining an average value (Osório et al., 1998).

All statistical analyses were performed using PROC UNIVARIATE and PROC MIXED of Statistical Analysis System (SAS, 2009) (version 9.2), at 0.05 probability level. The statistical design was completely randomized. The statistical model used is: $Y_{ij} = \mu + \alpha_i + \varepsilon_{ij}$, in which Y_{ij} represents the observation of crushed crambe level i in animal j; μ represents the means of dependent variables, α_i represents the fixed effect of crushed crambe i (i = 1, 2, 3, 4); and ε_{ij} represents the random error.

Results and discussion

Performance characteristics of the ewes were not affected ($p > 0.05$) by the replacement levels (Table 3). The average daily weight gain (0.150 kg day^{-1}) was lower than recommended (0.250 kg day^{-1}) by the NRC (2007) for adult ewes with moderate potential gain when feeding diets with 740 g kg^{-1} of total digestible nutrients.

The dry matter intake (DMI) in g day^{-1}, g kg^{-1} of body weight (g kg^{-1} BW) and metabolic size (MS) unit were not influenced by the levels of replacement, but DMI (g day^{-1}) was close to that expected (1 kg day^{-1}) (Table 2). These responses could be consequence of diets because they were isoenergetic. However, it was expected a reduction on DMI with increased crambe crushed in the diet, as it contains erucic acid and high consumption of this fatty acid can reduce feed intake by animals (Ítavo et al., 2016).

Canova, Bueno, Moreira, Possenti and Brás (2015) evaluating the replacement of soybean meal with crambe crushed, at 0, 220, 440 and 640 g kg^{-1} in concentrate for finishing lambs, observed a linear decrease in DMI, from 796 g day^{-1} in the control treatment to 687g day^{-1} in the last treatment, but with no effect on DMI in g kg^{-1} of BW and MS.

Table 3. Performance of ewes fed increasing levels of crambe crushed in the diet

Variables	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Initial body weight (kg)	46.44	41.80	46.64	41.52	3.10	ns
Final body weight (kg)	49.68	44.88	51.56	46.32	3.24	ns
Average daily gain (kg day^{-1})	0.16	0.15	0.15	0.15	8.26	ns
Total weight gain (kg)	3.15	3.16	4.83	4.89	0.45	ns
DM[1] intake (g day^{-1})	953.93	965.71	909.45	965.02	46.56	ns
DM intake (g kg^{-1} BW)	2.09	2.08	1.99	2.06	0.10	ns
DM intake (g kg^{-1})	53.05	52.79	51.16	52.27	1.92	ns
Feed conversion	6.32	6.64	6.22	6.33	0.39	ns
Feed efficiency	0.18	0.16	0.17	0.17	0.01	ns

[1]DM = dry matter; ns = non-significant at 0.05 probability; SEM = standard error of the mean.

Another important discussion related to variations in DMI refers to differences in gain composition caused by effect of body weight variation (Cabral et al., 2008), as it is known that intake is negatively related to the percentage of animals' body fat, which can justify the low DMI of animals in this study, once they had a low nutritional requirement.

The feed conversion (6.38) and feed efficiency (0.17) showed no linear effect. These indices are used in animal feeding as a way to measure the nutritional performance. Nevertheless, it should be noted that feed intake and weight gain are continuous, random, correlated variables and follow the normal probability distribution. Such indices are dependent on the type of feed, environmental conditions, body weight during the evaluation period, gain composition and health status of the animal (Pereira et al., 2010).

Variables organic matter (OM), neutral detergent fiber (NDF), total carbohydrates (TC) and non-fiber carbohydrates (NFC) intakes had no significant effect ($p > 0.05$), with mean values of 901.77 g day^{-1}; 291.11 g day^{-1}; 746.47 g day^{-1} and 459 g day^{-1}, respectively (Table 4). Levels of crambe crushed influenced ($p < 0.05$) only the ether extract (EE) and crude protein (CP) intakes of ewes (Table 4). EE intake showed a linear increase ($p < 0.05$), and this result is associated with the high level of this component in diets with higher proportion of crambe crushed (Table 2). The factors involved in intake regulation include energy intake by the animal and the NDF content of the diet.

Table 4. Nutrient intake, on a dry matter basis, by ewes fed increasing levels of crambe crushed in the diet.

Variables (g day^{-1})	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Organic Matter	915.01	922.48	868.21	901.36	31.89	ns
Ether extract[1]	17.23	20.76	20.86	41.28	1.70	0.0000*
Crude protein[2]	142.48	148.27	112.52	118.63	5.25	0.0066*
Neutral detergent fiber	291.36	293.95	283.06	296.07	10.25	ns
Total carbohydrates	755.78	753.45	735.00	741.65	26.35	ns
Non-fiber carbohydrates	467.05	462.02	458.68	448.25	16.28	ns

*Significant at 0.05 probability; ns = non-significant at 0.05 probability; SEM = standard error of the mean. [1]$Y = 7.12575 + 7.03532\,X;\ r^2 = 0.72$; [2]$Y = 161.513 - 12.6492\,X,\ r^2 = 0.62$.

This is considered limiting due to its slow degradation and low passage rate in the rumen. Values of EE above the maximum recommended level of 60 g kg^{-1} of total diet (NRC, 2007) may be a limiting factor for the DMI, because the degradation of the fiber may be impaired and it is believed the major effect is the coating of feed particles, which would impair colonization by rumen bacteria, especially cellulolytic ones, and consequently may negatively affect nutrient intake, whether by regulatory mechanisms controlling feed intake, or by the limited ability of ruminants to oxidize fatty acids.

In addition, another limiting fact is the presence of anti-nutritional factor in crambe, as glucosinolate, which can contribute to, along with the high content of EE, changes in DMI. Glucosinolate is considered toxic to livestock and potentially cause damage to the liver and other organs, also reducing the palatability, with negative consequences on growth, production and weight gain. This component is easily degraded by rumen microorganisms and adult animals are more tolerant when compared to young animals (Tripathi & Mishra, 2007).

For CP intake, there was a linear effect ($p < 0.05$), explained by the dietary CP content, which is inversely proportional to the levels of replacement (Table 2). As the intake is the variable that most affects animal performance, it is necessary to seek greater understanding of the influencing factors to enable a more accurate prediction, their variability throughout the productive life stages and under different dietary conditions.

The NDF and CNF digestibility coefficients were not significantly influenced ($p > 0.05$) by diets, with mean values of 0.54 and 0.84, respectively (Table 5). The high oil content in the diet is one of the factors that lead to reduced digestion of NDF, once oil available in the rumen environment can reduce the efficiency of fibrolytic bacteria.

The DM, OM, CP and TC digestibility coefficients decreased ($p < 0.05$) with the replacement levels of soybean meal by crambe crushed (Table 5). In addition, the oils, do not provide adenosine-tri-phosphate (ATP) to microbial growth, the higher level of this fraction and the higher interference with fiber digestibility, may occur reducing the digestion of other nutrients (Tripathi & Mishra, 2007).

Table 5. Apparent digestibility coefficient of nutrients in ewes fed increasing levels of crambe crushed in the diet.

Variables	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Dry matter[1] (0-1)	0.66	0.63	0.64	0.62	0.006	0.0324*
Organic matter[2] (0-1)	0.71	0.68	0.69	0.67	0.005	0.0166*
Ether extract[3] (0-1)	0.66	0.61	0.62	0.79	0.013	0.0005*
Crude protein[4] (0-1)	0.57	0.53	0.45	0.43	0.011	0.0000*
Neutral detergente fiber (0-1)	0.57	0.52	0.56	0.53	0.007	ns
Total Carbohydrates[5] (0-1)	0.74	0.71	0.73	0.71	0.005	0.0372*
Non-fiber carbohydrates (0-1)	0.85	0.84	0.84	0.83	0.004	ns

*Significant at 0.05 probability; ns = non-significant at 0.05 probability; SEM = standard error of the mean. [1]$Y = 0.667118 - 0.0108462\,X;\ r^2 = 0.69$; [2]$\hat{Y} = 0.718852 - 0.0112329\,X;\ r^2 = 0.69$; [3]$\hat{Y} = 0.568918 + 0.0394243\,X;\ r^2 = 0.39$; [4]$Y = 0.616881 - 0.0491450\,X;\ r^2 = 0.95$; [5]$Y = 0.747835 - 0.00954443\,X;\ r^2 = 0.36$.

The EE digestibility coefficient showed a linear effect ($p < 0.05$), with the highest value for animals fed diets with total replacement of soybean meal with crambe crushed (Table 5), which can be justified by the higher consumption of EE by these animals and the responses on DM and CT digestibility. Depending on the animal, the content of EE and NDF besides the CT content to be provided by concentrate are important, given the direct influence on intake and digestibility of nutrients, especially on performance. It is known effects on ruminal fermentation, intestinal motility, acceptance of feed, release of gut hormones and fat oxidation in the liver are involved in this process (Oliveira et al., 2009).

Physiological mechanisms involved in reduction of DMI when fat sources are included in ruminants diets are not well elucidated in the literature. The reduction of nutrient digestibility may be related to chemical effects of increased intake of unsaturated fatty acids in rumen and intestine, in high-fat diets (Silva et al., 2013), and toxic effects may occur to microorganisms. When in excess, the adsorption of free fatty acids from feed particles inhibits the direct contact of microbial cells with the substrate or the cellulose bond to bacterial cellulase, which may cause a reduction on nutrient digestion and reduction in microbial growth. The direct physical contact of the microorganism with feed particles is essential for digestion, especially of cellulose in the rumen.

No influence of replacement levels of soybean meal with crambe crushed ($p > 0.05$) was observed on carcass characteristics, except for the cold carcass yield (CCY) (Table 6), showing a linear effect ($p < 0.05$), decreasing responses with increasing crambe crushed inclusion, but with satisfactory values. The linear reduction, but with no statistical effects, of carcass compactness index (CCI) could influence the response of CCY because further compactness values are recommended, since they indicate a greater amount of muscle per cm, increasing their yield.

The loin eye area (LEA) response was the same verified for CCI, which was expected, since both are related to carcass muscularity. The LEA has a positive correlation with the amount of carcass meat, while subcutaneous fat thickness (SFT) correlates positively with the total amount of fat accumulated in animal body. As the diets had similar TDN values, the values of STF between diets were also similar. The STF mean value was 3.82 mm (Table 6), considered by Pinheiro, Silva Sobrinho and Andrade (2009) within a satisfactory range (2-5 mm).

Table 6. Characteristics of ewe carcasses finished with increasing levels of crambe crushed in the diet.

Variables	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Slaughter weight (kg)	42.31	42.12	44.86	45.17	3.61	ns
Hot carcass weight (kg)	20.78	19.15	17.57	18.56	1.53	ns
Cold carcass weight (kg)	19.55	17.99	16.52	17.23	1.40	ns
Hot carcass yield (%)	46.86	44.25	41.73	42.66	1.18	ns
Cold carcass yield (%)[1]	44.37	41.64	38.91	39.65	0.92	0.0188*
External carcass length (cm)	74.31	75.11	70.19	70.84	1.85	ns
Internal carcass length (cm)	58.00	59.06	58.86	56.84	1.60	ns
Leg Length (cm)	21.55	27.27	25.69	28.51	1.50	ns
Total length of leg (cm)	37.93	39.63	38.60	37.45	0.64	ns
Depth of the chest (cm)	29.40	31.46	31.05	32.10	1.03	ns
Hind perimeter (cm)	67.93	66.34	66.47	63.96	1.70	ns
Width of the rump (cm)	24.10	23.38	23.21	22.46	0.78	ns
Carcass compactness index (kg cm^{-1})	0.33	0.30	0.28	0.29	0.02	ns
Leg compactness index (kg cm^{-1})	0.64	0.59	0.60	0.60	0.02	ns
Maximum width (A) (cm)	5.26	5.48	4.83	5.00	0.17	ns
Maximum depth (B) (cm)	2.58	2.56	2.51	2.45	0.06	ns
Subcutaneous fat thickness (mm)	4.62	2.81	3.56	4.27	0.37	ns
Loin eye area (cm^2)	10.66	11.01	9.54	9.67	0.43	ns

*Significant at 0.05 probability; ns = non-significant at 0.05 probability; SEM = standard error of the mean. [1] $Y = 45.7451 - 1.8994x; r^2 = 0.80$.

The STF may be higher when animals feed on diets with higher forage proportion, because the ruminal digestion of this ingredient, improve the acetate production, which is the mainly precursor of body or milk fat. Besides, STF is an attribute that has an important role in meat tenderness for acting as an insulator, thus preventing the rapid carcass cooling, which produces shortening of sarcomeres and increases meat toughness.

Pinheiro et al. (2010) found values for *Longissimus* muscle measure A from 5.21 to 5.72 cm in sheep slaughtered at six years of age. These results are similar to the value listed in Table 6 (5.22 cm). Moreover, the same authors reported mean values of measure B from 2.28 to 2.60 cm, also similar to this study (2.52 cm). These measures evidence the development of *Longissimus* muscle, which, in this case, were similar because, in both experiments, animals were adults. *Longissimus* muscle measures A and B have been extensively studied due to the high correlation with carcass muscles proportion, and as an additional method to determine the muscle proportion in sheep carcasses.

The weight and yield of commercial cuts in relation to cold carcass were not affected ($p > 0.05$) by the replacement levels (Table 7) and these results were expected, once the animals were slaughtered with similar body condition, thus causing a standardization of carcasses.

The different cuts that comprise the sheep carcass have different economic values and the proportion of each represents an important index to assess the commercial quality of carcasses. Furusho-Garcia, Perez, Bonagurio, Lima and Quintão (2004) report that shoulder and leg account for more than 500 g kg^{-1} of carcass; these cuts best predict the total content of carcass tissues, which was also evidenced in Table 7, which together (shoulder and leg) reached 513 g kg^{-1} yield. However, among the variables analyzed, the leg showed the highest yield, which may be because it is the cut with greatest muscularity.

Table 7. Weight and yield of ewe cuts finished with increasing levels of crambe crushed in the diet.

Variables	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Neck (kg)	1.16	1.29	1.05	1.12	0.11	ns
Neck (g kg^{-1})	57.4	72.2	63.7	63.8	0.21	ns
Shoulder (kg)	3.43	3.19	3.13	3.08	0.23	ns
Shoulder (g kg^{-1})	177.6	178.6	188.5	181.4	0.24	ns
Rib (kg)	5.87	5.30	4.65	5.32	0.48	ns
Rib (g kg^{-1})	296.7	288.5	281.4	303.8	0.52	ns
Loin (kg)	2.65	2.43	1.99	2.25	0.21	ns
Loin (g kg^{-1})	133.3	134.4	120.9	132.0	0.31	ns
Leg (kg)	6.44	5.79	5.70	5.46	0.40	ns
Leg (g kg^{-1})	335.0	326.3	345.5	319.0	0.54	ns

ns = non-significant at 0.05 probability; SEM = standard error of the mean.

The percentages of different carcass cuts (Table 7) are consistent with the results obtained by Pires, Galvani, Carvalho, Cardoso and Gasperin (2006). However, these authors obtained these results in lamb carcass cuts, showing similar values regardless of animal age, even for sheep that have exceeded their performance.

There was no effect (p > 0.05) of diets on non-carcass components (Table 8). These results were expected, since they belong to an adult category of animal feeding diets with similar amount of energy and the same forage: concentrate ratio.

Ewes that received higher levels of fat presented the highest deposition of internal fat (48.9 g kg^{-1}), regardless of replacement levels. These deposits may occur depending on the animal maturity. Fat is the component that has greater variation due to nutritional level and a higher proportion of internal fat needs greater energy requirements for maintenance, due to increased metabolic activity of adipose tissue (Ferreira, Valadares Filho, Muniz, & Veras, 2000).

Table 8. Performance of the weight of non-carcass components in relation to slaughter weight of ewes finished with increasing levels of crambe crushed in the diet.

Variables (g kg^{-1})	g kg^{-1} dry matter crambe crushed				SEM	P > F
	0	50	100	150		
Blood	39.9	42.3	38.4	42.4	0.17	ns
Skin	127.4	141.8	142.8	154.1	1.16	ns
Paws	19.0	18.7	17.9	19.0	0.07	ns
Head	56.4	54.4	52.7	54.3	0.17	ns
Heart	3.8	4.0	3.7	4.3	0.01	ns
Kidneys	2.4	2.4	2.5	2.6	0.01	ns
Liver	17.7	21.1	17.4	20.2	0.09	ns
Lung + trachea	20.4	17.9	21.0	19.8	0.08	ns
Spleen	2.1	2.4	2.3	1.6	0.02	ns
Visceral fat	65.0	46.2	43.4	40.9	0.51	ns
Full gastrointestinal tract	201.7	215.0	173.1	263.8	1.04	ns
Empty gastrointestinal tract	70.1	79.6	78.0	85.9	0.32	ns

ns = non-significant at 0.05 probability; SEM = standard error of the mean.

The goal is a higher carcass yield in animals for slaughter, but not always carcasses with higher yield are the best, as they may have larger deposits of adipose tissue, which is not desirable. Therefore, it is necessary to produce animals that show high carcass yield, provided that it is consists of a large proportion of muscles and appropriate amount of fat, in order to protect the carcass during cooling and also to impart desirable sensory attributes to consumers. And the use of non-carcass components represents an important additional source of income that should be considered at the time of animals marketing, so that the producer may be well-paid.

Conclusion

Total replacement of soybean meal with crambe crushed in the diet for ewes does not alter the performance characteristics, however, influences the crude protein and ether extract intake, and nutrient digestibility, with exception of neutral detergent fiber and non-fiber carbohydrates. The crambe crushed can replace soybean meal in diets for animals in feedlots without affecting the carcass and non-carcass characteristics.

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