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Inclusion of different levels of common-bean residue in sheep diets on nutrient intake and digestibility

Inclusão de diferentes níveis do resíduo de feijão nas rações de ovinos sobre o consumo e digestibilidade dos nutrientes

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Abstract

The objective of this study was to evaluate the effect of including common-bean residue in diets for feedlot sheep on the intake and digestibility of nutrients by these animals. Sixteen intact male sheep were allotted in a completely randomized design with four treatments and four replicates. Treatments consisted of the inclusion of 0, 11, 22, and 33% of the common-bean residue (dry matter basis) in the experimental diets, which corresponded to the substitution levels of 0.0, 33.3, 66.7, and 100.0% of cottonseed cake for the bean residue. Data of the studied variables were subjected to analyses of variance and regression, adopting a significance level of 5%. The model was chosen based on the significance of the regression parameters, evaluated by the t test ($P<0.05$), and on the coefficients of determination. The levels of inclusion of the common-bean residue in the diet influenced ($P<0.05$) the intakes of dry matter (DM), crude protein, organic matter, ether extract, and indigestible neutral detergent fiber, expressed in g animal^{-1} day^{-1}, percentage of body weight (%BW), and metabolic weight ($BW^{0.75}$), which decreased linearly. However, the inclusion of the different levels of common-bean residue did not change ($P>0.05$) the intakes of neutral detergent fiber, non-fiber carbohydrates, or total digestible nutrients by the feedlot sheep. Every 1.0% of inclusion of the common-bean residue in the sheep diet led to a reduction of 4.93, 0.01, and 0.20 in DM intake when expressed in g animal^{-1} day^{-1}, %BW, and $BW^{0.75}$, respectively. Every 1.0% of inclusion of the bean residue resulted in the reduction of 2.73% in the intake of indigestible neutral detergent fiber by the feedlot sheep. Sheep displayed a linear increase ($P<0.05$) in water intake with the levels of common-bean residue in the experimental diets. The inclusion of 0, 11, 22, and 33% of the residue in the diet caused the digestibility of dry matter, crude protein, organic matter, and neutral detergent fiber to increase linearly ($P<0.05$). It is concluded that the inclusion of up to 22% of common-bean residue in diets for feedlot sheep provides balanced and adequate values between the intake and digestibility of nutrients.

Key words: Alternative feed, crude protein, feedlot, sheep

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Resumo

Objetivou-se avaliar o efeito da inclusão do resíduo de feijão na dieta de ovinos confinados sobre o consumo e a digestibilidade dos nutrientes. Foram utilizados 16 ovinos, machos inteiros, distribuídos em um delineamento inteiramente casualizado, com quatro tratamentos e quatro repetições. Os tratamentos foram constituídos pela inclusão de 0; 11; 22 e 33% na MS do resíduo de feijão nas dietas experimentais, as quais corresponderam aos níveis de substituição de 0,0; 33,3; 66,7 e 100,0% da torta de algodão pelo resíduo de feijão. Os dados das variáveis estudadas foram submetidos às análises de variância e de regressão, adotando-se o nível de significância de 5%. A escolha do modelo foi baseada na significância dos parâmetros de regressão, testada pelo teste t (P<0,05), e nos valores dos coeficientes de determinação. Os níveis de inclusão de resíduo feijão na dieta dos ovinos influenciaram (P<0,05) de maneira linear decrescente os valores de consumos de matéria seca, proteína bruta, matéria orgânica, extrato etéreo e fibra em detergente neutro indigestível expressos em g animal^{-1} dia^{-1}, percentagem do peso corporal (% PC) e peso metabólico (PC 0,75). Porém foi observado que a inclusão dos diferentes níveis de inclusão do resíduo de feijão não alterou (P>0,05) o consumo de fibra em detergente neutro, carboidratos não fibrosos e nutrientes digestíveis totais dos ovinos confinados. Observou-se que para cada 1,0% da inclusão do resíduo de feijão na dieta de ovinos ocorreu uma redução no consumo de MS de 4,93; 0,01 e 0,20 expressos em g animal^{-1} dia^{-1}, % PC e PC^{0,75}, respectivamente. A cada 1,0% de inclusão do resíduo de feijão foi observado a redução de 2,73% no consumo de fibra em detergente neutro indigestível dos ovinos confinados. Os ovinos apresentaram um aumentou linear (P<0,05) no consumo de água com a inclusão dos diferentes níveis do resíduo de feijão nas dietas experimentais. A inclusão de 0; 11; 22 e 33% do resíduo de feijão na dieta de ovinos influenciou de forma linear crescente (P<0,05) a digestibilidade da matéria seca, proteína bruta, matéria orgânica e fibra em detergente neutro. Assim, conclui-se que a inclusão até 22% do resíduo de feijão na dieta de ovinos em confinamento, promove valores equilibrados e adequados entre o consumo e a digestibilidade dos nutrientes.

Palavras-chave: Alimento alternativo, carneiros, confinamento, proteína bruta

Introduction

The forage production seasonality in certain times of the year represents one of the main factors causing the low productivity rates of animals on pasture. Thus, many strategies have been utilized to optimize the production system during the critical period of the year, among which is the use of the feedlot. However, its cost may be often considered elevated due to the higher participation of roughages and preserved foods in the animal diets.

According to Santos et al. (2011) feeding represents, on average, over 50% of the total cost of a feedlot, the concentrate fraction being the most costly part, as it represents around two-thirds of this value. Thus, the supply of agro-industrial wastes that meet the requirements of animals can optimize economic and environmental gains, reducing the feed costs and minimizing the deposition of residues in the environment. Carvalho (2006) reports that the elevation and the fluctuation of prices of energy and protein concentrates indicate the need for evaluating the possibility of substituting them for alternative low-cost, good-quality feeds that can maintain the current production level of herds.

In this scenario, many authors emphasize the use of the agro-industrial wastes and by-products to substitute commonly used feedstuffs (soybean meal, cottonseed meal, wheat bran, rice bran, corn, etc.) in the feedlot (CARVALHO et al., 2014, HOMEM JUNIOR et al., 2010; LOUVANDINI et al., 2007). Thus, the common-bean residue can be a feasible alternative in the feeding of feedlot sheep. Magalhães et al. (2008) reports that the common-bean residue can be classified as a protein concentrate feed, because of its high crude protein content, and that it also has considerable regional availability, since the common bean has been grow in all Brazilian states.

Today, Brazil is the second largest producer of common bean in the world, only after India, producing over three million tons yearly (CONAB, 2013). This production generates a residue that, if not directed to a safe and proper place, leads to environmental pollution, like all agro-industrial residues.

However, the residue from the common bean contains protease and hemagglutinin inhibitors, which can reduce its digestibility and nutritional value. Despite these anti-nutritional factors, Lajolo et al. (1996) stressed that it should be considered as an important source of nutrients to ruminants.

Nevertheless, for the livestock production sector to utilize this alternative feedstuff (common-bean residue) in the formulations and balancing of ruminant diets, previous technical-scientific knowledge should be generated about its composition and the appropriate levels of inclusion of this feed in ruminant diets and its effects on the intake and digestibility of nutrients.

Therefore, the objective of this study was to evaluate the effect of including common-bean residue in diets for feedlot sheep on the intake and digestibility of nutrients by these animals.

Material and Methods

The experiment was conducted in the animal metabolism shed at the Department of Animal Science of Universidade Federal de Mato Grosso, located in Rondonópolis - MT, Brazil. The experimental period was from May to June 2012, lasting 21 days, 15 of which were used for the sheep to adapt to diets and managements, and six for collection of samples of orts and feces. Sixteen intact male sheep of an unknown breed, with an approximate body weight of 30.5 ± 2.5 kg, at 12 ± 3 months of age, were used in the experiment. Animals were dewormed and allocated in individual 2-m^2 stalls provided with feeders, troughs for mineral salt, and drinkers.

A completely randomized design with four replicates was utilized, in which treatments consisted of the common-bean residue inclusion levels of 0, 11, 22, and 33% (% DM), corresponding to the levels of 0.0, 33.3, 66.7, and 100.0% of substitution of cottonseed cake for the residue in the DM of the experimental diets.

The feedstuffs utilized in the formulation of the experimental diets were cottonseed cake, ground corn, soybean meal, urea, common-bean residue, and corn silage (Table 1). The chemical composition of the feedstuffs utilized in the experimental diets is shown in Table 1.

Table 1. Chemical composition of the experimental feedstuffs, expressed in $g.kg^{-1}$ DM (corn silage, CS; soybean meal, SM; ground corn, GC; cottonseed cake, CC; and common-bean residue, CBR).

Variable	Ingredient, expressed in $g\ kg^{-1}$ DM				
	CS	SM	GC	CC	CBR
Dry matter	321.20	886.70	921.00	935.90	909.40
Organic matter	946.70	933.10	988.60	954.10	959.40
Crude protein	40.10	538.10	84.30	306.90	195.60
Ether extract	27.20	21.00	54.00	144.00	21.00
Mineral matter	53.30	66.80	13.00	45.80	40.60
NDFap[1]	558.10	224.80	218.20	352.10	373.60
ADF[2]	472.30	198.70	54.00	353.30	302.80
NFC[3]	340.50	149.30	632.20	151.20	298.80
iNDF[4]	307.50	15.70	7.50	102.00	152.20
TDN[5]	642.50	734.20	846.90	613.70	628.70

[1]NDFap: neutral detergent fiber corrected for ash and protein; [2]ADF: acid detergent fiber; [3]NFC: non-fiber carbohydrates; [4]iNDF: indigestible neutral detergent fiber, [5] TDN: estimated total digestible nutrients.

Experimental diets were formulated to contain 14% CP, including 45% corn silage, and 55% concentrate (DM basis), to provide an estimated daily gain of 200 g animal^{-1} (NRC, 2007). The centesimal composition of the experimental diets containing the different levels of inclusion of the common-bean residue and the chemical composition of the experimental diets are described in Table 2.

Table 2. Centesimal and chemical composition of the experimental diets for feedlot sheep containing different levels of inclusion of common-bean residue.

Ingredient	Inclusion of common-bean residue in the DM of the experimental diets (g kg^{-1} DM)			
	0	111	222	333
Corn silage	500.00	500.00	500.00	500.00
Ground corn	186.50	185.60	183.30	180.30
Soybean meal	10.40	11.30	12.60	13.50
Cottonseed cake	303.10	201.00	101.10	0.00
Common-bean residue	0.00	101.10	201.00	303.10
Urea	0.00	1.00	2.00	3.10
Variable (g kg^{-1} DM)	Chemical composition			
Dry matter	625.25	621.61	618.00	614.26
Organic matter	956.61	956.14	955.61	954.98
Crude protein	134.38	123.23	112.62	101.80
Ether extract	67.53	54.92	42.54	29.98
Mineral matter	43.65	43.12	42.66	42.20
NDFap[1]	428.80	430.63	432.56	434.66
ADF[2]	355.37	350.04	345.13	340.34
NFC[3]	335.53	349.87	363.35	376.81
iNDF[4]	186.22	191.20	196.22	201.44
TDN[5]	672.84	673.64	674.15	674.41

[1]NDFap: neutral detergent fiber corrected for ash and protein; [2]ADF: acid detergent fiber; [3]NFC: non-fiber carbohydrates; [4]iNDF: indigestible neutral detergent fiber, [5] TDN: estimated total digestible nutrients.

The common-bean residue originated from a company located in Cuiabá - MT that processes the bean. The residue was composed of damaged beans of the following sorts: whole (smashed, wrinkled, stained, and shell-less), cracked (good halves) and broken (good pieces), besides impurities such as stalks and pods. These residue components were ground through a 5-mm sieve. Samples of corn silage, common-bean residue, and other feeds from the concentrate, as well as orts and feces were stored in polyethylene containers for later analyses of the dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), mineral matter (MM), neutral detergent fiber (NDF), acid detergent fiber (ADF), and indigestible neutral detergent fiber (iNDF) contents, according to methods described by Detmann et al. (2012). The neutral detergent fiber (NDF) residue from the samples of feeds, orts, and feces was corrected for ash and nitrogen compounds, according to Licitra et al. (1996). Because of the presence of urea in the diets, the non-fiber carbohydrates (NFC) were calculated as proposed by Hall (2000): NFC = 100 - [(%CP - %CP from urea + % urea) + %NDFap + %EE + % ash].

The total digestible nutrients (TDN) content was calculated considering the intake and fecal excretion of the nutrients, using the following equation: TDN (%) = DCP + TDC + (DEE * 2.25), where TDC represents the total digestible carbohydrates; DCP, the digestible crude protein; and DEE, the digestible ether extract (BRODY, 1945). The iNDF of the feeds and orts was obtained by *in situ* incubation for 240 h (CASALI et al., 2008), followed by the analysis of neutral detergent fiber.

The experimental diets were supplied daily, twice a day, at preset times (07h30 and 15h30). The amount of feed to be supplied per animals was adjusted so as to allow for 10% orts, on a fresh-matter basis. On the last six days of the experiment, samples of the feed supplied, leftovers, and feces were obtained daily, frozen, and subsequently homogenized to form composite samples for later calculations of the intake and digestibility of the nutrients.

Between the 17th and 19th days, the water intake by the animals was measured as the daily difference between the volume supplied and leftover in buckets with millimeter lines. Buckets were washed upon every refill, and at the same time, two buckets with water were allocated in the facility to measure evaporation losses (SOUZA et al., 2010).

Total feces collection was performed using individual collection bags adapted to the animals through a breastplate. Collections were held twice daily, always before the feed was supplied. Next, samples were weighed and stored at -20 ºC for later analyses. The coefficients of digestibility of dry matter and nutrients of the diets were calculated as the difference between the amounts of each nutrient consumed and excreted in the feces.

All samples of feces and orts, referring to each experimental unit, corn silage, and concentrate feeds, were thawed, mixed, and homogenized. An aliquot was then collected, pre-dried in a forced-air oven at 65 ºC for approximately 72 h, and then ground in a Wiley mill with 1-mm sieves.

The data referring to the intake and apparent digestibility of the nutrients were subjected to analyses of variance and regression, adopting the 5% significance level. The model was chosen based on the significance of the regression parameters, tested by the t test ($P<0.05$), and on the coefficients of determination, according to the following statistical model: $Y_{ij} = \mu + t + e_{ij}$, where Yij = observed value of treatment i in replicate j; μ = effect of the overall mean; t = effect of each inclusion level; and eij = effect of the experimental error associated with all observations.

Statistical analyses were performed using the SAS (Sistema de Análises Estatísticas e Genéticas) statistical package (UFV, 1999).

Results and Discussion

The inclusion of the different levels (0, 11, 22, and 33 % DM) of common-bean residue in the sheep diets led to a linear decrease ($P<0.05$) in the intakes of dry matter (DM), crude protein (CP), organic matter (OM), ether extract (EE), and indigestible neutral detergent fiber (iNDF), expressed in g animal^{-1}day^{-1} (Table 3), %BW, and g DM kg^{-1} BW$^{0.75}$ (Table 4). However, the intakes of neutral detergent fiber (NDF), non-fiber carbohydrates (NFC), and total digestible nutrients (TDN) were not changed ($P>0.05$) with the inclusion of the different levels of common-bean residue in the experimental diets (Tables 3 and 4).

The reduction in the DM intake by the sheep with the addition of the common-bean residue to the diets may be attributed in part to the increase in the concentrations of NDF and iNDF in the diets (Table 2). Resulting from a greater concentration of these fractions in the common-bean residue compared with the cottonseed cake, another factor that might have contributed to the decreased intake is the low palatability of the common-bean residue caused by anti-nutritional factors.

Table 3. Average intakes (g animal^{-1}day^{-1}) of dry matter (DMI), crude protein (CPI), organic matter (OMI), neutral detergent fiber (NDFI), ether extract (EEI), non-fiber carbohydrates (NFCI), total digestible nutrients (TDNI), indigestible neutral detergent fiber (iNDFI), and water (mL animal^{-1} day^{-1}) by sheep fed diets containing levels of common-bean residue.

Variable	Inclusion of common-bean residue in the DM of the experimental diets (%)				CV (%)	Regression equation	R² (%)
	0%	11%	22%	33%			
DMI	1321.443	1268.342	1214.940	1164.399	10.53	Y=1316.66-4.932X	76.81
CPI	175.250	163.750	154.500	141.500	10.20	Y=170.925-0.950X	80.26
OMI	1324.686	1204.136	1180.683	1119.194	10.57	Y=1245.16-4.726X	87.21
NDFI	403.000	354.750	331.750	344.000	11.00	$\hat{Y}$=358.37	-
EEI	75.250	62.250	57.500	39.500	8.51	Y=75.425-1.018X	95.53
NFCI	852.111	829.639	795.535	794.588	9.95	$\hat{Y}$=817.96	-
TDNI	998.500	873.250	869.750	844.500	11.65	$\hat{Y}$=896.50	-
iNDFI	290.250	236.750	223.750	194.250	7.36	Y=281.400-2.736X	93.58
H_2O-I	738.750	942.200	970.300	1050.010	8.94	Y=793.125+7.897X	84.87

Table 4. Average intakes, expressed as a percentage of body weight (%BW) and in g DM kg^{-1} BW$^{0.75}$, of dry matter (DMI), crude protein (CPI), organic matter (OMI), neutral detergent fiber (NDFI), ether extract (EEI), non-fiber carbohydrates (NFCI), total digestible nutrients (TDNI), and indigestible neutral detergent fiber (iNDFI) by sheep fed diets containing levels of common-bean residue.

Variable	Inclusion of common-bean residue in the DM of the experimental diets (%)				CV[1] (%)	Regression equation	R² (%)
	0%	11%	22%	33%			
% BW							
DMI	4.292	4.162	3.972	3.800	13.24	Y=4.272-0.015X	75.92
CPI	0.900	0.500	0.330	0.260	9.29	Y=0.850-0.025X	89.14
OMI	4.060	4.007	3.772	3.549	10.28	Y=4.040-0.014X	81.31
NDFI	1.175	1.100	1.025	1.000	13.53	$\hat{Y}$=1.075	-
EEI	0.234	0.220	0.180	0.127	9.02	Y=0.254-0.009X	91.23
NFCI	2.750	2.650	2.500	2.480	20.57	$\hat{Y}$=2.595	-
TDNI	3.250	3.180	2.900	2.800	11.63	$\hat{Y}$=3.032	-
iNDFI	0.888	0.861	0.699	0.625	6.89	Y=0.935-0.023X	93.58
g DM kg^{-1} BW$^{0.75}$							
DMI	57.650	54.764	52.977	49.999	10.25	Y=56.535-0.203X	78.05
CPI	7.250	7.000	6.550	6.250	9.79	Y=7.250-0.034X	93.24
OMI	54.532	51.754	48.094	46.600	10.29	Y=53.463-0.195X	88.35
NDFI	16.500	15.000	14.750	13.000	10.05	$\hat{Y}$=14.812	-
EEI	3.000	2.750	2.250	2.000	9.14	Y=3.025-0.031X	98.00
NFCI	35.250	34.500	33.250	32.250	8.51	$\hat{Y}$=33.812	-
TDNI	42.000	41.000	36.250	35.950	10.69	$\hat{Y}$=38.800	-
iNDFI	12.000	11.250	9.500	8.500	8.12	Y=12.150-0.111X	97.80

[1] Coefficient of variation.

When expressed in %BW, the DM intake by the sheep decreased linearly ($P<0.05$) with the inclusion of the common-bean residue in the experimental diets (Table 4), with a reduction of 0.01 percentage units with every 1.0% of inclusion of the residue in the diets. Likewise, Magalhães et al. (2008) substituted soybean meal for common-bean residue at 0, 5.2, 10.4, and 15.6% of the DM of lactating cow diets and observed a decrease in the intakes of DM, OM, CP, and EE. According to these authors, the low palatability of the common-bean residue as a consequence of the presence of tannins, and the increased dustiness of the concentrates, which, when in contact with saliva, form a pasty material that complicates chewing, contributed to these results. Despite the higher levels of inclusion of the common-bean residue, these factors were not observed in the present study with sheep. According to NRC (2007), for the weight range utilized in the experiment, the intake as a percentage of live weight should be around 4.15%, which is close to the range found in the present study from 4.29%, for the control treatment, to the 3.80 obtained with the highest level of inclusion of the common-bean residue.

A study conducted by Silva et al. (2005) evaluating the inclusion levels of 15 and 30% of cocoa meal and palm kernel cake in goat feeding demonstrated that the average DM intake (%BW) was 4.16%, which is very close to the 4.05% (%BW) obtained in the present study. Similar results were also found by Lousada Júnior et al. (2005), who worked with the waste from fruit processing in sheep feeding and obtained an average DM intake of 4.4% BW with the inclusion of guava waste in the diets.

The DM intake expressed in g DM kg^{-1} $BW^{0.75}$ decreased by 0.20 percentage units with every 1.0% inclusion of common-bean residue in the diet for the feedlot sheep (Table 4). This factor is possibly attributed to the increase in the fiber content when the common-bean residue was added to the diet.

In the present study, it was found that every 1.0% of inclusion of common-bean residue in the diet caused a reduction of 0.95 percentage units in CP intake expressed in g $animal^{-1}day^{-1}$ (Table 3), which is related to the decline in DM intake and in the portion of the nutrient in question in the diets when the common-bean residue was added.

According to NRC (2007), sheep of moderate growth, with an average weight gain of 250 g $animal^{-1}$ day^{-1} and a body weight above 20 kg, require an intake of 167 g day^{-1} CP. The animals fed the diets containing the different levels of inclusion of common-bean residue showed a CP intake below the recommended: 163.75, 154.50, and 141.50 g $animal^{-1}$ day^{-1} for the common-bean residue inclusion levels of 11, 22, and 33%, respectively (Table 3).

The observed values for CP intake by the sheep receiving the different levels of common-bean residue in the present study were close to the 149 g day^{-1} observed by Souza et al. (2004); 170 g day^{-1}, by Santos et al. (2008), and 166 g day^{-1}, by Ferro (2014), who utilized the inclusion of coffee husks, soybean hulls, and common-bean residue, respectively, in sheep diets.

The inclusion of common-bean residue in the sheep feeding provided a decrease of 0.02 percentage units with every 1% of the common-bean residue added on the CP intake expressed as %BW. However, CP intake expressed in g kg^{-1} $BW^{0.75}$ decreased by 0.03 percentage units with every 1% of inclusion of the common-bean residue in the experimental diets (Table 4).

In a study evaluating cashew nut meal at the inclusion levels of 0, 12, 24, and 36% (DM basis) in the feeding of feedlot sheep, Rodrigues et al. (2003) observed a linear decrease in CP intake in g $animal^{-1}day^{-1}$, %BW, and g CP kg^{-1} $BW^{0.75}$. The authors attributed this decreasing linear response of CP intake to the reduction of DM intake, which occurred as a result of the increase in the NDF content in the diets with the inclusion of the nut meal, similarly to what occurred in the present study with the inclusion of the common-bean residue in the diets (Table 2).

The inclusion of common-bean residue did not change (P>0.05) the NDF intake by the sheep, whose mean values were 358.37 g animal^{-1} day^{-1}, 1.07% BW, and 14.81 g kg^{-1} BW$^{0.75}$, as shown in Tables 3 and 4. The average NDF intake in %BW (1.07%) was close to the 0.8 and 1.2% BW suggested by Van Soest (1994) for ruminants. However, it must be emphasized that high NDF contents in the diet limit DM intake but lead to a greater NDF intake when expressed in %BW.

According to Rodrigues et al. (2003), the use of cashew nut in the feeding of sheep in the finishing phase influenced the NDF, which decreased linearly and showed average values of 496.29 g animal^{-1}day^{-1}, 2.02% BW, and 45.15 g NDF kg^{-1} BW$^{0.75}$. These results were higher than those observed in the present study.

The EE intake expressed in g animal^{-1}day^{-1}, %BW, and g kg^{-1} BW$^{0.75}$ decreased linearly (P<0.05) with the addition of common-bean residue to the experimental diets (Table 3).

This result obtained for EE intake can be explained by the greater concentration of this component in the cottonseed cake (Table 1). Thus, the inclusion of the common-bean residue provided a reduction of the amount of cottonseed cake and consequently a reduction in the total EE content of the experimental diets containing higher levels of the common-bean residue. Another factor that might be related is the decrease in DM intake when the common-bean residue was added.

Likewise, Magalhães et al. (2008) evaluated starea and common-bean residue in steers diets and also observed a decrease in the EE intake of the animals fed the highest levels of the common-bean residue. A study conducted by Ferro (2014) to evaluate the use of common-bean residue in sheep feeding demonstrated lower EE intake by sheep fed the highest levels of inclusion of common-bean residue, and this reduction of EE intake was attributed to the lower concentration of this nutrient in the common-bean residue when it substituted the cottonseed cake as it was included in diets for feedlot sheep.

No difference was found (P>0.05) in the intakes of NFC and TDN (Tables 3 and 4) by the sheep fed the common-bean residue. However, TDN intake remained within the range considered ideal by NRC (2007), which recommends the TDN intake of 0.8 kg animal^{-1} day^{-1} for finishing sheep. The lack of effects on NFC intake may be attributed to the fact that common-bean residue contains a larger portion of this nutrient compared with the cottonseed cake (Table 2); therefore, even with the reduction of DM intake, this nutrient was not changed.

The inclusion of 0, 11, 22, and 33% of common-bean residue in the sheep feeding caused a linear decrease (P<0.05) in iNDF intake. This variable decreased by 2.73 g animal^{-1}day^{-1}, 0.02% BW, and 0.11 g kg^{-1} BW$^{0.75}$ with every 1.0% of inclusion of the common-bean residue (Tables 3 and 4). These results referring to iNDF intake by the sheep are probably attributed to the lower DM intake and to the increase in the concentration of iNDF in diets containing common-bean residue.

According to Van Soest (1994), the increase in the iNDF fraction of diets tends to reduce the passage rate of the feed in the rumen and consequently extend the residence time of the feeds in the different compartments of the gastrointestinal tract. The author also stressed that the food fiber performs a physiological function in the regulation of the operation of the gastrointestinal tract of ruminants, altering the control of intake, the rumen distension, and the digestibility of nutrients.

Ferro (2014) observed that the iNDF intake by sheep fed diets containing common-bean residue was 170.52 g animal^{-1} day^{-1}, which is much lower than the 236.25 g animal^{-1} day^{-1} obtained in the present study. This difference between studies may be explained by the larger portion of this component in the diets of the current study as compared with that of Ferro (2014).

Water intake increased by 7.89 percentage units with every 1% of inclusion of the common-bean residue in the experimental diets (Table 3), which can be explained by the increase in the dietary NDF content with the inclusion of the residue (Table 2). According to Van Soest (1994), coarser feeds require a higher energy expenditure, which causes the animal to take more time ruminating, which would thus lead to an increase in water intake.

The average water intake of 925.3 mL animal^{-1} day^{-1} kg^{-1} of DM consumed is below the 2,870 mL recommended by NRC (2007). The average temperature during the experiment was 25 ºC, and this factor might have influenced the low water intake compared with the NRC (2007) recommendations, because at this temperature it can be inferred that the physiological effort made by the animals to maintain homeothermy was minimum. According Neiva et al. (2004), after the ambient temperature of 25 ºC, the rectal temperature of the sheep increases, which leads to difficulty dissipating heat, consequently elevating the water intake.

The inclusion of the levels of 0, 11, 22, and 33% of the common-bean residue in the feeding of feedlot sheep provided a linear increase ($P<0.05$) in the digestibility coefficients of DM, CP, OM, and NDF, as shown in Table 5. The increase in the digestibility of these nutrients was probably a result of a lower passage rate of the digesta caused by the lower intake of the diets containing a higher percentage of common-bean residue.

Table 5. Apparent digestibility of dry matter (DMD), crude protein (CPD), organic matter (OMD), neutral detergent fiber (NDFD), ether extract (EED), and non-fiber carbohydrates (NFCD) in sheep fed diets containing levels of common-bean residue.

Variable	Inclusion of common-bean residue in the DM of the experimental diets (%)				CV[1] (%)	Regression equation	R^2 (%)
	0	11	22	33			
DMD	68.635	71.022	72.970	76.412	5.58	Y=68.468+0.229X	98.56
OMD	70.327	72.537	74.320	77.560	5.18	Y=70.164+0.213X	98.02
CPD	74.797	77.087	79.037	81.325	4.37	Y=74.832+0.195X	99.00
NDFD	33.822	39.527	41.110	55.715	10.58	Y=32.496+0.609X	86.65
EED	87.532	90.362	92.857	92.070	4.69	$Y=87.385+0.393-0.007X^2$	97.40
NFCD	90.375	90.465	90.442	90.805	15.80	$\hat{Y}=9.521$	-

[1] Coefficient of variation.

According to Santos et al. (2009), the addition of 8% of canola grains and by-products to sheep diets resulted in similar values for the intake and digestibility of the animals. The authors explained that the decrease in the passage rate in the animals that were fed the diets with the highest level of canola residue led to an increase in the residence time of the digesta in the gastrointestinal tract, which caused a longer time of exposure of the feeds to the digestive process, consequently increasing the total apparent digestibility values in percentage terms.

However, studying diets without forages in goat feeding, Bava et al. (2001) observed lower digestibility coefficients for the diets containing the highest levels of forage. These authors attributed this effect of the digestibility coefficient to a higher passage rate of the diets without forages, i.e., with a higher amount of easily-fermentable carbohydrates (concentrate).

According to the regression equation demonstrated in Table 5, an increase of 0.22 percentage units in the digestibility of DM was detected with every 1.0% of inclusion of the common-bean residue in the experimental diets. The estimated values for the digestibility coefficient of DM were 68.63%, 71.02%, 72.97%, and 76.41% for the inclusion levels of 0, 11, 22, and 33% of common-bean residue in the DM of the diets, respectively. However, evaluating the effective degradability of the DM from halves of common-bean, Marcondes et al. (2009) obtained 77.82% in cattle diet.

Every 1.0% of inclusion of the common-bean residue in the sheep diets provided an increase of 0.19 percentage units in the CP digestibility (Table 5). According to Ferro (2014), the lower neutral detergent insoluble protein content, associated with the lower concentration of acid detergent fiber present in the common-bean residue compared with the soybean meal, might have contributed to the increased digestibility of the CP in diets containing common-bean residue.

The effect observed on the digestibility coefficient of OM with the increase in the levels of inclusion of common-bean residue (Table 5) can be attributed to the high effective degradation rate of this fraction. This result is also in line with Ferro (2014), who also observed an increase in the digestibility of OM as the common-bean residue was added to feedlot-sheep diets.

The increasing linear response of NDF digestibility with the diets containing the different levels of inclusion of the common-bean residue varied from 33.82% for the diet containing 0% of the residue to 55.71% for the diet with 33% of this ingredient, which provided an increase of 0.60 percentage units for every 1.0% of inclusion of the common-bean residue (Table 5). This result can be explained by the longer period of retention of the feed in the rumen of the sheep fed the diets containing higher levels of the residue, possibly resulting from the increased fiber content (Table 2).

The digestibility coefficient of EE responded quadratically ($P<0.05$) as the levels of inclusion of the common-bean residue were increased, with a maximum point of 92.90% for the level of 28.07% of inclusion. This upward trend might be a consequence of the increased digestibility of DM (Table 5).

Magalhães (2005) worked with the substitution of soybean meal for common-bean residue at the levels of 0, 20, 40, and 60% in the concentrate in diets for dairy sheep, and obtained an increase in the digestibility of EE. The authors attributed this factor to the biosynthesis from non-lipid components. However, Ferro (2014) did not observe differences for the digestibility coefficient of EE with inclusion of common-bean residue in sheep feeding, obtaining an average of 85.49% for this variable, which was close to the 90.70% observed in the present study.

The different levels of common-bean residue in the feeding of feedlot sheep did not change ($P>0.05$) the digestibility of the NFC, which averaged 90.52% (Table 5). However, a study conducted by Ferro (2014) demonstrated that the inclusion of common-bean residue in sheep feeding provided a linear increase in the digestibility of NFC.

Thus, it is concluded that the inclusion of up to 22% of common-bean residue in the feeding of feedlot sheep provides better balance between the intake and digestibility of nutrients.

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