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Production and quality of beef from young bulls fed diets supplemented with peanut cake

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ABSTRACT

Peanut cake is a biodiesel byproduct that has been tested as an alternative feed additive for use in cattle production. This study aimed to assess the importance of dietary peanut cake inclusion for young bull growth rate, beef production, and beef quality. In total, 32 Nellore young bulls individually housed in stalls with a mean initial body weight of 390 ± 43.5 kg were distributed in a completely randomized design for the experiment. The animals were fed Tifton 85 hay and one of four concentrate mixtures with 0, 33, 66 or 100% peanut cake instead of soybean meal. There was a linear reduction ($P < 0.05$) in the slaughter weight and hot carcass weight and a quadratic effect ($P < 0.05$) on the beef texture. No alterations occurred in the physicochemical characteristics of the longissimus thoracis; however, changes were observed ($P < 0.05$) in the longissimus thoracis fatty acid profile. The replacement of soybean meal with peanut cake at levels up to 100% in the diet of feedlot-finished young bulls promotes a beneficial increase in the levels of PUFAs and the following nutraceutical compounds: conjugated linoleic acid (CLA) and Ω3 and Ω6 fatty acids.

1. Introduction

Brazil has the world's largest commercial cattle herd with approximately 200 million heads (MAPA, 2014) and a production of approximately 9.3 million tons of carcasses per year (USDA, 2014). Since 2004, Brazil has consolidated itself as the largest beef exporter, selling its products to more than 180 countries (MAPA, 2014). However, the use of new technologies is essential to increase beef production and improve its quality to meet the internal and external demands and, thus, consolidate existing markets and access new markets.

The concept of beef quality is relative because, in addition to the chemical composition, other parameters including the appearance, juiciness, texture and color are important for product acceptance by consumers (Domingues et al., 2015; Baba, Kallas, Costa-Font, Gil, & Realini, 2016). Beef quality, in turn, may be affected by animal nutrition, and several byproducts of biodiesel production may be used as viable alternatives in animal feed (Gonzaga Neto et al., 2015; Oliveira, Palmieri, et al., 2015; Oliveira, Faria, et al., 2015).

Peanut (*Arachis hypogaea*) has become a key economic alternative crop among oilseeds cultivated for biodiesel production. The byproduct of the extraction of peanut seed oil has a high nutritional value, particularly regarding protein levels (41 to 45%) and lipids (8 to 9%) (Silva, Medeiros, et al., 2015; Gonzaga Neto et al., 2015), with a chemical composition comparable to that of soybean meal (Silva, Oliveira, et al., 2015), a traditional and costly ingredient in animal feed.

This study evaluated the carcass traits, physicochemical characteristics and fatty acid profile of beef from feedlot-finished young bulls fed diets supplemented with peanut cake.

2. Materials and methods

2.1. Location, animals and diets

This study was performed in strict accordance with the recommendations in the Guide for the National Council for Animal Experiments Control (CONCEA). The protocol was approved by the Committee on the Ethics of Animal Experiments of the Federal University of Bahia, Bahia State, Brazil (Permit Number: 03-2012). The animals were slaughtered by captive bolt, as per the requirement for the welfare of

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the animals in the Industrial Inspection and Sanitary Regulation of Animal Products, and all efforts were taken to minimize suffering.

The experiment was conducted in the period from November 2010 to March 2011 at the Experimental Farm of the School of Veterinary Medicine and Animal Science, Federal University of Bahia, located in the city of São Gonçalo dos Campos, Bahia State, Brazil.

Thirty-two entire Nellore young bulls were used, eight per experimental diet, with an initial mean body weight of 390 ± 43.5 kg and mean age of 15 months. The animals were individually housed in 2.0 × 4.0 m stalls that were partially covered and equipped with feeders and drinkers. Measurements of animal weights were performed at baseline and every 28 days during the trial.

The diets, consisting of peanut cake, soybean meal, ground corn, mineral premix, urea and ammonium sulfate at a 9:1 ratio (urea S/A) and Tifton 85 hay (Table 1), were formulated to be isonitrogenous (15% crude protein, CP) and isocaloric (65% total digestible nutrients, TDNs), with a 40:60 roughage: concentrate ratio in the form of a mixed total diet, according to the guidelines from the National Research Council (NRC, 2000) for daily gains of 1.2 kg (Table 2).

The experimental diets contained four amounts of peanut cake (0, 33, 66 and 100%) as a replacement for the soybean meal in the concentrate, with ground corn and Tifton 85 hay as roughage (Table 2).

The animals were fed twice daily at 8:00 am and 4:00 pm, according to the dry matter (DM) intake on the previous day, to maintain the percentage of daily leftovers at 10% of the feed supply and avoid limiting the intake. Samples of the concentrate ingredients, roughage and leftovers were collected and stored at −20 °C for subsequent analyses.

2.2. Analyses of nutrients and diet

The samples of food and leftovers were predried at 55 °C for 72 h; ground in a Wiley mill (Tecnal, Piracicaba City, São Paulo State, Brazil) with a 1 mm sieve; stored in air-tight, plastic containers (ASS, Ribeirão Preto City, São Paulo State, Brazil); and sealed properly until laboratory analysis was performed for the DM levels, ash, CP and ether extract (EE) (Methods 967.03, 942.05, 920.29 and 981.10, respectively; AOAC, 1990). To determine the neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents, the methodology of Van Soest, Robertson, and Lewis (1991) was used, with the modifications that were proposed in the Ankom device manual (Ankom Technology Corporation, Macedon, New York, USA). The correction of NDF and ADF for the nitrogen compounds and the estimation of the neutral (NDIN) and acid (ADIN) detergent insoluble nitrogen compounds were performed according to Licitra, Hernandez, and Van Soest (1996). The non-fiber carbohydrates (NFCs) were obtained according to Mertens (2002). The TDNs were calculated using the formula estimates of digestibility for each analytical fraction given by the NRC (2001). The ingredient percentages and chemical composition are shown in Table 2.

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

Item	Ingredients			
	Ground corn	Soybean meal	Peanut cake	Tifton 85 hay
Dry matter[a]	94.43	95.76	96.46	85.70
Mineral matter[b]	1.36	7.05	5.26	7.30
Crude protein[b]	7.10	44.91	44.52	6.96
Ether extract[b]	2.65	2.06	14.71	1.31
Neutral detergent fiber[b,d]	11.84	25.91	17.60	80.35
Acid detergent fiber[b]	4.39	20.01	15.55	55.09
Lignin[b]	0.08	0.22	6.85	9.90
Hemicellulose[b]	5.46	9.29	11.31	27.80
Non-fiber carbohydrates[b]	77.04	20.07	17.91	4.08
Neutral detergent insoluble nitrogen[b]	1.71	5.00	2.68	0.76
Acid detergent insoluble nitrogen[b]	2.85	2.72	1.99	0.41
Estimated TDNs [c]	86.50	72.25	78.22	53.65

[a] Values as a percentage of the natural matter.
[b] Values as a percentage of the dry matter.
[c] Total digestible nutrients, estimated using the equations given by the NRC (2001).
[d] Corrected for ash and protein.

Table 2
Composition of experimental diets.

Ingredients (%)	Peanut cake (%)			
	0	33	66	100
Peanut cake	0.00	4.08	8.16	12.23
Soybean meal	12.16	8.10	4.05	0.00
Ground corn	44.88	44.91	44.94	44.91
Mineral premix[a]	1.52	1.48	1.43	1.43
Urea S/A[b]	1.43	1.43	1.43	1.43
Tifton 85 hay	40.00	40.00	40.00	40.00
Chemical composition				
Dry matter[c]	91.27	91.29	91.32	91.35
Mineral matter[d]	4.39	4.32	4.25	4.18
Crude protein[d]	15.70	15.56	15.42	15.42
Ether extract[d]	1.96	2.48	3.00	3.51
Total carbohydrates[d]	77.94	77.64	77.33	76.89
Neutral detergent fiber[e]	40.61	40.28	39.95	39.61
Acid detergent fiber[d]	26.44	26.26	26.09	25.91
Non-fiber carbohydrates[d]	38.65	38.59	38.52	38.42
Estimated TDNs[f]	69.07	69.35	69.64	69.88

[a] Levels of active elements (per kg): calcium 240.00 g; phosphorus 174.00 g; copper 1250.00 mg; cobalt 100.00 mg; iron 1795.00 mg; iodine 90.00 mg; manganese 2000.00 mg; selenium 15.00 mg; zinc 5270.00 mg; and fluorine 1740.00 mg.
[b] Urea and ammonium sulfate at a 9:1 ratio.
[c] Values as a percentage of the natural matter.
[d] Values as a percentage of the dry matter.
[e] Corrected for ash and protein.
[f] Total digestible nutrients, estimated using the equations given by the NRC (2001).

2.3. Carcass traits, beef quality and fatty acid profile

At the end of confinement, the animals were weighed after a 14 h period of fasting from solids and were slaughtered the same day in a commercial slaughterhouse by mechanical stunning followed by bleeding, skinning and evisceration. The carcasses were identified and weighed to assess the hot carcass weight (HCW) and hot carcass yield (HCY) following slaughter. Subsequently, they were refrigerated for 24 h at 2 °C. The right side of the carcass was used to assess the following quantitative carcass traits: carcass length (CL), leg length (LL), cushion thickness (CT), rib eye area (REA) and subcutaneous fat thickness (SFT).

The carcass length was measured using a measuring tape to determine the distance from the anterior edge of the pubic bone to the medial, cranial edge of the first rib. An aluminum caliper compass was used to determine the leg length, measuring the distance between the anterior edge of the pubic bone and the medial point of the bones of the tarsal joint. The cushion thickness was assessed using an aluminum caliper compass to measure the distance between the lateral and medial sides of the upper portion of the cushion using a measuring tape.

The section between the 10th and 13th ribs on the right half carcass was removed according to the methodology described by Hankins and Howe (1946) and adapted by Muller (1987). The subcutaneous fat thickness was measured using a precision caliper at three equidistant points in the cut region between the 12th and 13th ribs. The rib eye area was also assessed at that point, in cm^2, using a standard planimeter. Subsequently, all the portions removed from the right half carcasses were frozen for analysis. The evaluations of beef color and texture were performed in the section removed from the right half carcass, according to the 1 to 5 scale proposed by Muller (1987). The texture was scored with grade values from 5 (very fine) to 1 (very coarse), and the color was scored with grade values from 5 (bright red) to 1 (dark).

The sections removed from the half carcasses for the laboratory analyses were thawed at room temperature and each dissected using a scalpel and knife to obtain the longissimus thoracis muscle, from

which samples were collected to assess the physicochemical characteristics of the muscle.

Moisture was evaluated by the AOAC (1990) method 950.46, and protein was analyzed using the micro-Kjeldahl method (AOAC, 1990; item 928.80) for the determination of total nitrogen. The CP content was calculated by multiplying the total nitrogen by 6.25. The ether extract and ash content were determined according to AOAC (1990) items 960.39 and 920.153, respectively. For the measurement of moisture content, the samples were subjected to the infrared balance method, using a Master model ID200 balance. One-gram aliquots were separated and subjected to 175 °C for 20 min. Three replicates were prepared per sample, and the mean value of each sample was used in the data analysis.

After cooling at ambient temperature, the samples were again wrapped in foil and kept refrigerated for 12 h at 4 °C. At least six cylinders (diameter of 1.27 cm) were cut from the flesh (in a direction longitudinal to the muscle fibers) to be evaluated for Warner–Bratzler shear force (WBSF) according to Holman, Alvarenga, Van de Vem, and Hopkins (2015). The instrumental texture analysis was performed on a TAXT2 texturometer (Stable Micro Systems Ltd., Vienna Court, UK) at a speed of 200 mm/min using standard shear blades with a thickness of 1.016 mm and a blade size of 3.05 mm. The instrumental texture analysis was performed according to Holman et al. (2015).

Three beef slices, each 2 to 2.5 cm thick, measured using a ruler, were used for the analysis of cooking weight losses. The samples were weighed on semianalytical scales, packaged in aluminum foil and baked on a plate preheated at a temperature of 150 °C. The samples were turned after reaching 35 °C and maintained until the internal temperature reached 72 °C (the temperature was monitored using a digital thermometer). After removing the samples from the aluminum foil, still at a temperature above 70 °C, the slices were cooled to room temperature and reweighed. The difference between the initial weight and final weight of the sample indicated the weight loss by cooking.

The water-holding capacity was calculated using a centrifugal method according to Nakamura and Katoh (1985); that is, 1 g of ground sample was weighed using filter paper and centrifuged for 4 min at 1500 × *g* after drying in an oven at 70 °C for 12 h.

The pH measurement was performed using a bench pH meter (Digmed). For that purpose, 50 g of each sample was mixed in a 200 ml beaker and blended in a Turrax homogenizer with 10 ml of distilled water to enable electrode penetration. Prior to analysis, the pH meter was adjusted using a pH 7 buffer solution. Three measurements were considered replicates, and the mean value per animal was used for data analysis.

The extraction of total sample lipids was performed according to the method of Bligh and Dyer (1959), and transesterification was performed according to method 5509 of the International Organization for Standardization (ISO, 1978). The fatty acids were esterified according to the technique described by Hatman and Lago (1973) and analyzed using an Agilent gas chromatograph (HP6890 model) equipped with a flame ionization detector (FID) and Supelco SP2560 capillary column (100 m × 0.25 mm × 0.2 μm). The injector and detector temperatures were maintained at 250 °C and 280 °C, respectively. The temperature gradient used for the separation of fatty acid esters was 140 °C for 5 min, increasing 1.6 °C/min to 210 °C, standing for 10 min, increasing 10 °C/min to 240 °C and standing for 15 min, for a total run of 76 min. The carrier gas (N_2) flow was 30 ml/min. The injection volume was 1.2 μl. The peak areas of the methyl esters of the fatty acids were measured using the ChromQuest 4.1 software.

The identification of fatty acids was performed following the verification of the equivalent chain length (ECL) of the peaks (Visentainer & Franco, 2006) and a comparison of the sample retention times with those of the standard samples of methyl esters of fatty acids containing the linoleic acid isomers cis-9, trans-11 and trans-10, cis-12 (189–19, O-5632 and O-5626 Sigma, USA), as reported by Simionato et al. (2010).

The quantification of fatty acids was based on the area normalization method (Visentainer & Franco, 2006), for which the concentration of fatty acids is expressed as a relative percentage of the % total lipids (Table 3).

2.4. Statistical analysis

The experimental design was completely randomized, with four experimental diets and eight replicates. All of the traits under study were tested for normality. Those showing a normal distribution were analyzed with regression equations, using the linear mixed-effects model (MIXED) procedure to assess the linear and quadratic effects of the levels of supplementation with peanut cake. The means of the experimental diets were calculated using the least squares means (LSMEANS) option.

The statistical model used was the following:

$$Y_{ij} = \mu + t_i + e_{ij},$$

where

Y_{ij} = the value observed relative to experimental diet i;

μ = the overall mean;

t_i = the effect of experimental diet i for i = 0, 33, 66 or 100%; and.

e_{ij} = the random error associated with each observation with j replicates, where j = 1, 2, 3, 4, 5, 6, 7 or 8.

The results from the analyses of the carcass traits, proximate composition, chemical composition, physicochemical traits and fatty acid profile were interpreted by an analysis of variance and regression, using the Statistical Analysis System (SAS 9.1®, 2003) at 5% significance. The subjective evaluations of texture and color were analyzed by the Kruskal–Wallis test, with the nonparametric Mann–Whitney U-test used to check the significance of the contrasts.

Table 3
Fatty acid profile of ingredients and experimental diets (%).

Fatty acids	Ingredients				Peanut cake (%)			
	Corn	Soybean meal	Peanut cake	Tifton 85 hay	0	33	66	100
C16:0 (palmitic)	15.10	19.30	12.87	27.33	20.05	19.80	19.55	19.29
C18:0 (stearic)	6.22	5.86	2.97	3.60	4.94	4.83	4.72	4.60
C18:1n-9 (oleic)	17.23	16.00	48.97	7.60	12.72	14.07	15.43	16.77
C18:2n-6 (linoleic)	44.95	51.65	30.00	16.72	33.14	32.28	31.43	30.54
C18:3n-3 (α-linolenic)	0.38	4.17	0.11	0.00	0.68	0.51	0.35	0.18
C18:3n-6 (linolenic)	1.77	0.39	0.13	39.41	16.61	16.60	16.59	16.58
C20:0 (arachidic)	1.31	0.58	0.95	5.83	2.99	3.01	3.02	3.04
C20:3n-6 (eicosatrienoic)	1.48	0.95	1.62	0.00	0.78	0.81	0.84	0.86
C20:1 (gadoleic)	0.13	0.15	1.26	0.00	0.08	0.12	0.17	0.21

3. Results

Average daily weight gain (ADG) showed a negative linear response (P = 0.015) due to the low DM intake ratio driven by the peanut cake levels. Although the diets contained similar protein and energy levels, the higher lipid content of the peanut cakes affected the intake and ADG. The higher lipid levels may be favorable because they increase the energy density; however, the increased intake of this fraction may reduce the total DM intake, consequently reducing the CP, vitamin and mineral intake, explaining the change in the ADG.

The slaughter (P = 0.035) and hot carcass weights (P = 0.040) decreased linearly with the increase in dietary levels of peanut cake (Table 4). The values found in this study for the ADG were 1.41, 1.31, 1.28 and 1.04 kg for the animals fed diets supplemented with 0, 33, 66 and 100% peanut cake, respectively.

The beef texture showed a quadratic effect (P = 0.044) with the substitution of peanut cake for soybean meal. By contrast, the thickness of the subcutaneous fat showed a linear tendency (P = 0.0589) to decrease with the increasing inclusion of peanut cake in the diet.

The hot carcass yield (P = 0.826), carcass length (P = 0.213), cushion thickness (P = 0.976), leg length (P = 0.694), rib eye area (P = 0.337) and beef color (P = 0.870) were not affected by the level of peanut cake replacing soybean meal.

There was no effect on the CP (P = 0.535), mineral matter (P = 0.145), moisture (P = 0.434), shear force (P = 0.509), weight loss by cooking (P = 0.726), water-holding capacity (P = 0.232) or pH (P = 0.513) of the longissimus thoracis muscle of young bulls fed diets supplemented with peanut cake instead of soybean meal (Table 5). A quadratic tendency (P = 0.0931) for altered lipids occurred with an increased inclusion of peanut cake in the diet.

There was a linear decrease with an increase in the percentage of peanut cake in the diet in C14:0 (P = 0.000) and C16:0 (P = 0.001) saturated fatty acids (SFAs) and in C14:1 (P = 0.045) unsaturated fatty acids (UFAs). By contrast, linearly increasing behavior was observed with the addition of peanut cake to the supplement concentrate for C21:0 (P = 0.007) docosapentaenoic acid (DPA) (P = 0.009) and Ω3 (P = 0.003) (Table 6).

With peanut cake addition (100%), the fatty acid content of the longissimus thoracis muscle of young bulls presented a positive quadratic relationship regarding the C12:0 SFA (P = 0.002), the C15:1 (P = 0.018) and C24:1 (P = 0.011) UFAs, the C18:2n-6c (P = 0.005), C18:3n-6c (P = 0.010) and C20:3n-6c (P = 0.037) polyunsaturated fatty acids (PUFAs), the PUFA group (P = 0.004), CLA (P = 0.009) and Ω6 (P = 0.001) as well as the ratios of Ω3:Ω6 (P = 0.016) and PUFAs:SFAs (P = 0.007).

There were tendencies toward a linear decrease in the C16:1 (P = 0.074) UFAs and toward a quadratic change in the C17:0 (P = 0.099) and C23:0 (P = 0.059) SFAs, the C18:1n-7c (P = 0.083) UFAs and the C18:3n-3c (P = 0.050) PUFAs with the increasing inclusion of peanut cake in the diet.

There was no effect of the inclusion of peanut cake in the diet on the C15:0 (P = 0.437), C18:0 (P = 0.126), C20:0 (P = 0.950) or C20:0 (P = 0.166) SFAs; the C17:1 (P = 0.234), C18:1n-9c (P = 0.748) or C22:1n-9c (P = 0.169) UFAs; or the C20:4n-6c (P = 0.501) PUFAs.

Similarly, there was no change in the monounsaturated fatty acid (MUFA, P = 0.621), SFA (P = 0.770) or docosahexaenoic acid (DHA, P = 0.176) levels present in the longissimus thoracis muscle of young bulls fed the diets supplemented with peanut cake instead of soybean meal.

Table 5
Physical characteristics of the longissimus thoracis muscle of young bulls fed diets supplemented with peanut cake instead of soybean meal.

Item (NM[a]%)	Peanut cake (%)				SEM[b]	P-value	
	0	33	66	100		Linear	Quadratic
Crude protein	24.06	23.17	24.12	23.29	24.06	0.535	0.975
Mineral matter	1.16	1.10	1.06	1.09	1.16	0.145	0.242
Lipids	5.46	3.93	4.57	5.06	5.46	0.793	0.093**
Moisture	73.28	72.19	73.84	74.11	73.28	0.434	0.592
Shear force, kgf/cm^2	3.09	2.84	2.77	2.73	3.09	0.509	0.780
Weight loss by cooking, g/100 g	35.24	37.18	37.97	36.34	35.24	0.726	0.500
Water-holding capacity, %	0.55	0.50	0.52	0.51	0.55	0.232	0.257
pH	5.22	5.18	5.19	5.15	5.22	0.513	0.976

[a] Data analyzed based on the natural matter (NM).
[b] SEM = standard error of the mean.

4. Discussion

The decrease in the slaughter weight of the animals supplemented with peanut cake instead of soybean meal is related to the decrease (P = 0.015) in the ADG (1.14, 1.31, 1.28 and 1.04 for the 0, 33, 66 and 100% treatments, respectively). The changes in hot carcass weight were consistent with the changes in the slaughter weight. Considering that the carcass weight is the main component of trade between producers and beef packers and represents the market value of the animals (Baba et al., 2016), it is important that the hot carcass weights assessed exceeded the minimum threshold (230 kg) for avoiding penalizing the carcass value of young bulls, with an estimated body weight of 450 kg.

The ether extract increase with the peanut cake inclusion did not affect the hot carcass yield, carcass length, cushion thickness, leg length or the rib eye area or color. Cushion thickness is a trait directly related to the carcass length and leg length, traits that also remained unaltered in this study. The rib eye area is a trait that represents the level of muscle development of the animals; this area is related to the yield of higher

Table 4
Carcass traits of young bulls fed diets supplemented with peanut cake instead of soybean meal.

Item	Peanut cake (%)				SEM[a]	P-value	
	0	33	66	100		Linear	Quadratic
Average daily weight gain, kg	1.14	1.31	1.28	1.04	0.05	0.015*	0.524
Slaughter weight, kg	538.43	516.86	516.43	499.56	5.77	0.035*	0.847
Hot carcass weight, kg	294.71	275.93	280.43	271.25	3.33	0.040*	0.501
Hot carcass yield, %	54.79	53.35	54.32	54.26	0.27	0.826	0.242
Carcass length, cm	142.28	140.57	141.28	140.00	0.53	0.213	0.857
Cushion thickness, cm	28.56	27.11	29.30	27.90	0.44	0.976	0.977
Leg length, cm	84.28	84.50	83.78	85.12	0.55	0.694	0.618
Subcutaneous fat thickness, mm	3.04	3.56	2.70	2.44	0.1511	0.058**	0.240
Rib eye area, cm^2	63.71	62.43	67.00	62.25	0.99	0.337	0.880
Texture, pointsb	3.86	3.28	3.57	3.75		P = 0.5229	
Color, pointsb	4.00	3.71	4.00	3.94		P = 0.2320	

[a] SEM = standard error of the mean.
[b] Analyzed by the Kruskal–Wallis test.
* Significant differences: P < 0.05.
** Linear tendency.

Table 6
Profile of fatty acids present in the longissimus thoracis muscle of young bulls fed diets supplemented with peanut cake instead of soybean meal.

Fatty acids (%)	Peanut cake (%)				SEM[a]	P-value	
	0	33	66	100		Linear	Quadratic
C12:0	2.78	2.05	1.86	3.23	0.143	0.413	0.002*
C14:0	2.80	2.89	1.95	1.81	0.079	0.000	0.629
C14:1	0.23	0.14	0.11	0.15	0.014	0.045*	0.066
C15:0	0.27	0.28	0.23	0.25	0.015	0.437	0.921
C15:1	0.18	0.17	0.11	0.22	0.011	0.702	0.018*
C16:0	25.46	25.42	24.16	22.50	0.295	0.001*	0.231
C16:1	2.27	1.80	2.05	1.62	0.097	0.075**	0.964
C17:0	0.75	0.81	0.83	0.73	0.022	0.897	0.099**
C17:1	0.67	0.67	0.63	0.61	0.016	0.234	0.773
C18:0	16.58	18.22	22.52	19.25	0.784	0.126	0.158
C18:1n-7 t	0.72	0.81	0.92	0.93	0.049	0.125	0.690
C18:1n-7c	1.95	1.34	1.45	1.73	0.113	0.587	0.083**
C18:1n-9c	36.71	38.87	38.11	36.08	0.813	0.748	0.247
C18:2n-6c	4.92	3.66	4.10	5.89	0.253	0.190	0.010*
C18:3n-6c	0.47	0.38	0.30	0.52	0.033	0.789	0.037*
C18:3n-3c	0.09	0.20	0.13	0.15	0.009	0.110	0.050**
C18:2c9t11	0.13	0.15	0.10	0.20	0.011	0.195	0.116
C20:0	0.24	0.20	0.32	0.20	0.015	0.950	0.142
C20:3n-6c	1.33	0.93	1.13	1.78	0.077	0.051	0.005*
C20:4n-6c	0.030	0.007	0.009	0.020	0.003	0.501	0.112
C21:0	0.15	0.09	0.14	0.24	0.012	0.007*	0.006
C22:1n-9c	0.18	0.16	0.17	0.24	0.013	0.169	0.132
C23:0	0.30	0.24	0.23	0.37	0.020	0.377	0.057**
C24:0	0.17	0.09	0.19	0.20	0.011	0.166	0.146
C24:1	0.06	0.04	0.05	0.09	0.004	0.065	0.011*
DPA[b]	0.64	0.49	0.63	0.93	0.037	0.009*	0.013
DHA[c]	0.06	0.04	0.07	0.07	0.004	0.176	0.379
SFAs[d]	49.46	50.29	49.95	48.78	0.827	0.770	0.581
MUFAs[e]	42.93	43.86	43.60	41.64	0.859	0.621	0.440
PUFAs[f]	7.61	5.86	6.44	9.57	0.362	0.078	0.004*
CLA[g]	5.05	3.81	4.20	6.09	0.251	0.161	0.009*
Ω3	0.76	0.73	0.81	1.16	0.042	0.003*	0.048
Ω6	1.82	1.31	1.43	2.32	0.087	0.067	0.001*
Ω3:Ω6	0.41	0.60	0.56	0.52	0.020	0.126	0.016*
PUFAs:SFAs	0.15	0.12	0.13	0.20	0.008	0.072	0.007*

[a] SEM = standard error of the mean.
[b] DPA = docosapentaenoic acid.
[c] DHA = docosahexaenoic acid.
[d] SFAs = saturated fatty acids.
[e] MUFAs = monounsaturated fatty acids.
[f] PUFAs = polyunsaturated fatty acids.
[g] CLA = conjugated linoleic acid.
* Significant differences: $P < 0.05$.
** Significant differences: $P < 0.10$.

commercial value cuts and is affected by multiple factors, including the slaughter weight and genetic group. The detected values averaged 63.85 cm^2 (Table 4). The beef color was classified as red, averaging 3.91 points. This characteristic can be decisive for the choice of beef by consumers. The beef color observed in the present experiment proves that dietary supplementation with peanut cake does not alter color in young bulls.

The increase in peanut cake provided fat deposition in the carcass, with the greatest deposition occurring in intermuscular fat, followed by subcutaneous fat and, finally, intramuscular fat; this mostly intermuscular fat deposition affects the carcass structure. The results of the present study regarding subcutaneous fat thickness were close to those found by Domingues et al. (2015), who showed that the main factor increasing this carcass trait is the diet energy content, which most likely increases with the addition of peanut cake in animal diets. It is noteworthy that the layer of subcutaneous fat in the latter study, which averaged 2.98 mm, only met the minimum prerequisites of beef packers (3 mm) necessary to avoid penalization of the carcass value.

According to Demirel, Ozpinar, Nazli, and Keser (2006), fat thickness, slaughter age and weight, breed, the application of hormones and nutrition can influence the fatty acid profile of beef. In the present study, the thickness of subcutaneous fat correlated with the fatty acid profile for the longissimus thoracis muscle of young bulls fed diets supplemented with peanut cake instead of soybean meal. The texture of the beef changed quadratically, perhaps in association with the higher amount of lipids in carcasses from animals fed more peanut cake in the concentrate.

The inclusion of peanut cake did not affect the CP, mineral matter or moisture content of the longissimus thoracis muscle of young bulls. The mean observed moisture values were 72.19, 73.28, 73.84 and 74.11; thus, the results from the present study are within the range of values reported in the literature (Domingues et al., 2015; Machado Neto et al., 2015).

The shear strength of food products is a parameter for evaluating quality when assessing changes in beef performance during and after cooking. The results found in the present study were similar among diets, which indicates that supplementation with peanut cake instead of soybean meal did not affect the tenderness of the longissimus thoracis muscle. The mean value found in this study, 2.85 kgf/cm^2, is typical of tender beef, while values above 5.00 kg/cm^2 are typical of tough beef (Lawrie, 2005).

Shear force, weight loss by cooking, water-holding capacity and pH were not affected, further demonstrating the potential for replacing soybean meal with peanut cake. The mean pH value was 5.18, a level considered optimal (Mach, Bach, Velarde, & Devant, 2008). The beef final pH or acidification corresponds to the accumulation of lactic acid resulting from ATP resynthesis from glucose derived from the glycogen stores (Domingues et al., 2015).

The profile of the fatty acids of the longissimus thoracis muscle was affected by replacing soybean meal with peanut cake. Changes were observed in the SFAs, MUFAs and PUFAs (Table 6) and in the sum and ratio of fatty acids (Table 6), possibly because of the change in the dietary lipid profile (Table 3).

The fatty acid profile is directly related to the total carcass fat (Wood et al., 2008), especially the intramuscular fat (Bressan et al., 2011). In general, animals fed the highest amount of peanut cake (100%) showed the meat marbled with the greatest percentage of UFAs. In isocaloric diets, it is not uncommon to see similar fatty acid profiles (Darley et al., 2010; Bressan et al., 2011).

Another key factor is the modification of fatty acids in the rumen, known as biohydrogenation, which tends to convert oleic, linoleic and linolenic acids into stearic acid (C18:0). The chemical composition of the longissimus thoracis muscle (Table 5) indicates similarity in the lipid levels among treatments, although the nature of the lipids is highly variable and dependent on the feeding conditions, digestion, intestinal absorption, liver metabolism and transport system of the lipids (Geay, Bauchart, Hocquette, & Culioli, 2001).

The C12:0 (lauric) fatty acid showed a quadratic effect, which may have resulted from the process whereby fatty acids with a chain smaller than 12 carbons, in general, are extended before they are incorporated into tissues (Prado et al., 2015).

The C14:0 (myristic) and C16:0 (palmitic) fatty acids decreased linearly with the increase in the dietary levels of peanut cake. These fatty acids are considered hypercholesterolemic because they are responsible for the increase in the amount of low-density lipoproteins (LDL), which cause coronary heart disease (Ito et al., 2012). C14:0 is the most undesirable because it is more rapidly incorporated into cellular triglycerides (Rioux, Lemarchal, & Legrand, 2000). Among the SFAs, stearic acid (C18:0) was not influenced by diet (Table 3) and, despite being saturated, is not regarded as atherogenic or hypercholesterolemic because the body rapidly converts stearic to oleic acid, a MUFA (Gómez et al., 2015).

The percentage of C14:0 and C16:0 in the longissimus thoracis muscle is considered high, approximately 35% of total fatty acids (Oliveira, Palmieri et al., 2015). The decrease in those fatty acids in beef fed peanut cake is a beneficial effect of using this cake in the diets of feedlot cattle.

The C21:0 (heneicosanoic) fatty acid showed a quadratic increase with increased dietary peanut cake, which most likely resulted from a rise in the ruminal production of propionate because a large part of dietary concentrate undergoes fermentation by ruminal microorganisms,

providing an increased production of volatile fatty acids, particularly propionate (Baba et al., 2016).

Ruminal microorganisms synthesize fatty acids, and some of them thereby complicate the identification of dietary effects on the fatty acid profile of muscle. This phenomenon may be observed in the levels of the C14:1 (myristoleic) fatty acid (Wu, Ohajuruka, & Palmquist, 1991), which showed a linear reduction with increasing peanut meal in the present study. The levels of the C15:1 (pentadecenoic) fatty acid, a fatty acid that is typical of ruminal metabolism, changed quadratically. Thus, the animals in this study showed a difference in the metabolism of that acid in the rumen, and this difference may have been associated with the different diets.

The levels of the C18:2n-6c (linoleic) and C18:3n-6c (y-linolenic) fatty acids had a quadratic effect, which was not expected because soybean is richer than peanut cake in linoleic acid (Table 3). Linoleic acid is present in larger amounts in grains than in forages and diets rich in grains, such as those in feedlotting, resulting in beef with a more unsaturated lipid profile, according to French et al. (2000). The C18:2n-6c and C18:3n-3c fatty acids are the only ones considered essential, and their intake is desirable because they have key functions in the structure of cellular membranes and metabolic processes. A quadratic diet effect occurred on the levels of C20:3n-6c (eicosatrienoic) and C22:5 (docosapentaenoic) fatty acids, and this effect most likely resulted from the conversion of linolenic acid into these acids (Baba et al., 2016).

The modifications that occurred in the SFAs and MUFAs were insufficient to change the sum (stearic acid, C18:0) of these categories of fatty acids, most likely because the principal UFA remained unchanged.

The levels of the total PUFAs and those of the C18:2n-6c (linoleic), C18:3n-6c (y-linolenic), C20:3n-6c (eicosatrienoic) and C22:5 (docosapentaenoic) fatty acids, which together represent 95.32% of the total PUFAs, were influenced by the diets (Table 6). According to Sami, Koegel, Eichinger, Freudenreich, and Schwarz (2006), the PUFA and intramuscular fat contents are negatively correlated due to the dilution of a relatively constant quantity of phospholipids and an increase in triglycerides with increased beef marbling. This combination reduces the content of extractable phospholipids in the structural components of the PUFA-rich muscle cells.

A quadratic effect occurred on the total CLA because the diets had the same effect on the C18:2n-6c (linoleic) fatty acid, which corresponds to 96.97% of the CLA analyzed. The term CLA refers to a group of PUFAs that are produced in the rumen during the biohydrogenation of linoleic and α-linolenic acids by fermentative bacteria (*Butyrivibrio fibrisolvens*) or synthesis via the Δ-9 desaturase of vaccenic acid (C18:1 trans-11; Onogi et al., 2015).

The levels of docosapentaenoic acid (C22:5) had a direct effect on the total Ω3 acids, promoting a quadratic effect, whereas the C20:3n-6c (eicosatrienoic) fatty acid was the main lipid responsible for the quadratic effect on the Ω6 acids.

In this study, the mean Ω3:Ω6 ratio was 0.52; that is, there was two times more Ω6 than Ω3. An inappropriate balance of these groups of essential fatty acids (high Ω6:Ω3 ratio) contributes to the development of diseases, while an optimal balance may help in the maintenance or even in the recovery of full health, according to a study conducted by the School of Medicine of the University of Maryland (2014). A healthy diet should contain no more than 4–5 times more Ω6 than Ω3.

The PUFA:SFA ratio was 0.15 in this study, which is considered low compared with the recommended value for a healthy diet of higher than 0.4 (Guerrero et al., 2015). However, Scollan et al. (2001) stated that this ratio is low in beef, at approximately 0.1. The PUFA:SFA ratio reflects the quality of fat ingested by consumers (Oliveira, Faria, et al., 2015). The use of peanut cake in the animals' diet promoted better results than those found when using soybean meal in terms of the beef quality, total CLA, total polyunsaturated acids and PUFA:SFA ratio, factors that are strongly correlated with the risk for cardiovascular disease (Gladyshev et al., 2015).

5. Conclusion

The replacement of soybean meal with peanut cake at levels up to 100% in the diet of feedlot-finished young bulls does not promote significant changes in carcass traits or beef quality, although it modifies the fatty acid profile of the longissimus thoracis, with a beneficial increase in the levels of polyunsaturated fatty acids.

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