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Effects of palm kernel cake (*Elaeis guineensis*) on intake, digestibility, performance, ingestive behaviour and carcass traits in Nellore bulls

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Abstract

The objective of the current experiment was to determine the effects of increasing levels of palm kernel cake in a finishing diet on feed intake, digestibility, performance, ingestive behaviour and carcass traits in zebu bulls. Thirty-two Nellore bulls (420 ± 25.0 kg initial body weight [BW] and 24-months-old), were assigned randomly to individual pens with four treatments (0, 70, 140 and 210 g/kg of palm kernel cake by total dry matter [DM]) and eight replicates per treatment. The inclusion of palm kernel cake linearly decreased DM, crude protein and non-fibrous carbohydrate intake and increased ether extraction intake and digestibility. There was a linear decrease in final BW and hot carcass weight (HCW) associated with palm kernel cake inclusion in the bull diet. However, the gain : feed ratio was similar among the diets. Eating and rumination rates (g DM or neutral detergent fibre/h) were reduced, whereas the total chewing time and idling (min/day) were not affected by palm kernel cake inclusion. There were no effects of palm kernel cake inclusion on most quantitative carcass characteristics and qualitative carcass attributes (subcutaneous fat thickness, longissimus muscle area, colour, texture and marbling). The inclusion of palm kernel cake (up to 210 g/kg total DM) in beef cattle finishing diets decreased eating and rumination rates, thereby decreasing average daily gain and, consequently, final BW and HCW. However, qualitative carcass attributes were not affected by the use of palm kernel cake.

Introduction

In cattle production, the high cost of concentrate feed ingredients has prompted the testing of new unconventional alternatives for inclusion in the diet. One alternative that has been widely tested is supplementation with co-products of the biofuel industry (Cerutti *et al*., 2016), because the biofuel industry has created new options for ruminant production systems by generating meals and cakes as co-products of the oil extraction process (Bezerra *et al*., 2015; Medeiros *et al*., 2015). These co-products can be low-cost alternatives for animal feeding, replacing conventional ingredients (maize and soybean) without negatively impacting (de Gouvêa *et al*., 2015; Santana Filho *et al*., 2015; Costa *et al*., 2016), or even increasing, weight gain and improving the quality of meat (Owaimer *et al*., 2004; Shi *et al*., 2014; Uchockis *et al*., 2014). In particular, palm kernel cake can potentially be used in beef cattle feeding, especially in finishing diets, in which greater proportions of concentrate are used to increase energy intake and the rate of body weight (BW) gain in a short period of time (Santana Filho *et al*., 2015; Visoná-Oliveira *et al*., 2015; Santos *et al*., 2016).

Palm kernel cake is a product of the extraction of oil from *Elaeis guineensis*, which is a perennial palm tree. The diversity of favourable soils and a suitable climate for the cultivation of oil palm increases the availability of its residues throughout the year mainly in arid regions (Gonzaga *et al*., 2015; Lima *et al*., 2015; Oliveira *et al*., 2015*a*, 2015*b*). These residues can potentially be used in animal feed because of the chemical composition of the cakes (Ferreira *et al*., 2012; Silva *et al*., 2013; Abubakr *et al*., 2015; Pimentel *et al*., 2015). However, the high lipid content (ether extract-EE, 110 g/kg) along with the low-quality fibre content (acid detergent fibre-ADF, 421 g/kg) of palm kernel cake can decrease animal intake and reduce digestibility and performance due to interference with fibre digestion or diet palatability (Sanders *et al*., 2015; Santana Filho *et al*., 2015). In addition, the inclusion of neutral detergent fibre (NDF) at a concentration of approximately 610 g/kg alters the

Table 1. Chemical composition of ingredients of the experimental diets

Analytical fraction	Ground maize	Soybean meal	Palm kernel cake	Tifton-85 grass
Dry matter (g/kg as fed)	888	892	935	903
Ash (g/kg DM)	12.3	65.5	27.4	66.6
Crude protein (g/kg DM)	68.2	480	124	78.9
Ether extract (g/kg DM)	47.6	20.0	186	15.1
Neutral detergent fibre$_{ap}$ (g/kg DM)	67.6	154	559	657
Acid detergent fibre (g/kg DM)	34.0	79.4	421	350
NDIP (g/kg CP)	332	160	467	418
ADIP (g/kg CP)	292	65.6	325	328
Non-fibre carbohydrates (g/kg DM)	804	281	104	183
Cellulose (g/kg DM)	23.8	70.2	275	301
Hemicellulose (g/kg DM)	33.6	74.9	138	306
Acid detergent lignin (g/kg DM)	10.2	9.20	146	49.1

DM, dry matter; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein.

physical mechanisms of intake, and low-quality fibre fills the rumen, thereby reducing the intake capacity and, consequently, the ingestive behaviour of animals (Mertens, 1997; Gonzaga *et al.*, 2015).

Thus, based on the chemical composition of palm kernel cake, it is possible to hypothesize that it can be added to the feed of Nellore bulls to improve performance and carcass traits without affecting the ingestive behaviour of the animals. Based on the above considerations, the objective of the current study was to determine the effects of increasing levels of palm kernel cake in a finishing diet on intake, digestibility, performance, ingestive behaviour and carcass characteristics in Nellore bulls.

Materials and methods

Animal care and experimental design

The experiment was conducted at the Experimental Farm of the School of Veterinary Medicine and Animal Science of the Federal University of Bahia located at São Gonçalo dos Campos, State of Bahia, Brazil.

Thirty-two Nellore bulls (420 ± 25.0 kg initial BW and 24 months old) were individually allotted to 32 partially covered pens (2.0×4.0 m^2) with concrete floors, feed bunks and water cups. The experiment was conducted over an 84-day period that was preceded by 15 days of animal adaptation to the facilities, management and diets. The experimental design was completely randomized, with four dietary treatments with eight replicates each. Four inclusion levels of palm kernel cake constituted the treatments: 0, 70, 140 and 210 g/kg of the total DM content of the diet.

Diets and chemical composition

The total mixed ration (TMR) was composed of 0.35 Tifton-85 grass hay (*Cynodon* spp.) chopped to a mean length of 5 cm as roughage and 0.65 concentrate compound consisting of ground maize, soybean meal, mineral salt and palm kernel cake at different levels. Palm kernel cake was obtained following mechanical oil extraction (MF Rural®, Salvador, Bahia, Brazil). Then, it was ground and mixed with the other feed ingredients so that the large pieces of cake formed by pressing could be broken and homogenized with the rest of the diet. Palm kernel cake was included with a concomitant decrease of soybean and ground maize. Water was supplied *ad libitum*. Before the experiment, the feed components were subjected separately to chemical analysis (Tables 1 and 2) with triplicate samples.

The diets were formulated according to the recommendations of the National Research Council (NRC, 2000) and contained 15.8 g/kg of crude protein (CP), for an estimated average daily gain (ADG) of 1200 g/day.

The TMR was weighed daily for the individual recipes and was divided equally into two meals, offered at 09.00 and 16.00 h, to allow a proportion of 0.10 refusals. After a period of 24 h, the refusals were weighed and meals adjusted. Samples of diet ingredients as well as the concentrates and uneaten feed were collected weekly and frozen (−20°) for further chemical analysis (in triplicate).

All samples were dried in a forced-air oven at 55 °C for 72 h. The samples were ground using a Wiley mill with a 1 mm sieve and composited for each 28-day period for each treatment. The samples were stored at ambient temperature until analysis. The DM, CP, ash and EE contents of the diets and feed refusals were determined by standard methods (AOAC, 2000) (930.15, 976.05, 942.05 and 920.39, respectively).

Neutral detergent fibre and ADF were determined according to Van Soest *et al.* (1991). Correction of the ash and protein contents of the NDF was conducted as recommended by Mertens (2002), and the non-fibrous carbohydrate content (NFC) of the dietary ingredients was calculated from the difference as follows (Mertens, 1997):

$$\mathrm{NFC} = 100 - \mathrm{NDF} - \mathrm{CP} - \mathrm{EE}$$

Neutral detergent insoluble nitrogen (NDIN) and acid detergent insoluble nitrogen were obtained according to the recommendations of Licitra *et al.* (1996).

The dietary digestible energy (DE) was converted to metabolizable energy (ME) using an efficiency of 0.82 (NRC, 2000). In the diet it was estimated to be 4.409 Mcal/kg of total digestible nutrients (TDN, according to Weiss, 1999).

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Table 2. Ingredients and chemical composition of the experimental diets

	Palm kernel cake g/kg (DM basis)			
Ingredient	0	70	140	210
Tifton-85 hay (g/kg DM)	350.0	350.0	350.0	350.0
Ground maize (g/kg DM)	504.9	446.3	387.7	329.1
Soybean meal (g/kg DM)	115.1	103.7	92.3	80.9
Palm kernel cake (g/kg DM)	0.00	70.0	140.0	210.0
Urea[a] (g/kg DM)	15.0	15.0	15.0	15.0
Mineral mixture[b] (g/kg DM)	15.0	15.0	15.0	15.0
Analytical fraction				
Dry matter (g/kg as fed)	867	871	874	877
Ash (g/kg DM)	37	38	38	38
Crude protein (g/kg DM)	159	158	158	157
Ether extract (g/kg DM)	32	42	51	61
Neutral detergent fibre (g/kg DM)	282	315	349	382
Acid detergent fibre (g/kg DM)	149	176	202	229
NDIP (g/kg CP)	332	344	355	367
ADIP (g/kg CP)	46	66	87	107
Non-fibre carbohydrates (g/kg DM)	502	452	402	351
TDN (g/kg DM)	703	701	697	699
Cellulose (g/kg DM)	126	143	160	177
Hemicellulose (g/kg DM)	304	317	292	286
Acid detergent lignin (g/kg DM)	23	33	42	52
Digestible energy[c] (MJ/kg)	13.0	12.9	12.8	12.9
Metabolizable energy[c] (MJ/kg)	10.6	10.6	10.5	10.6
Net energy for maintenance[c] (MJ/kg)	7.20	7.20	7.11	7.15
Net energy for gain[c] (MJ/kg)	4.31	4.31	4.27	4.31

DM, dry matter; NDIP, neutral detergent insoluble protein; ADIP, acid detergent insoluble protein;
[a]Mixture of urea and ammonium sulphate (9:1).
[b]Guaranteed levels (per kg, in active elements): calcium (max.) – 220.00 g and calcium (min.) – 209.00 g; phosphorus – 163.00 g; sulphur – 12.00 g; magnesium – 12.50 g; copper – 3500 mg; cobalt – 310 mg; iron – 1960 mg; iodine – 280 mg; manganese – 3640 mg; selenium – 32 mg; zinc – 9000 mg; and fluorine (max.) – 1630 mg.
[c]Calculated according to NRC (2001)

Intake, digestibility and performance

Dry matter intake was measured daily for each animal throughout the experimental period as the difference between the amount of feed supplied and refusals. Dry matter and nutrient intake were estimated as the difference between the total content of each nutrient in the supplied feed and the total content of each nutrient in the refusals.

The digestibility assay was performed between days 60 and 64 of the experimental period, based on collections of the total refusals and partial faeces collections during this period. For the collection of faeces, appropriate canvas bags were attached to the animals using nylon strips to reduce inconvenience to the young bulls. After an acclimation period of 4 days to allow adaptation of the bulls to the canvas bags, two daily faecal collections (11.00 and 17.00 h) were conducted for 8 consecutive days. The faeces and refusals were dried in a forced-air oven at 55 °C for 72 h. Then, the refusal samples were ground to a 1-mm size in a Wiley knife mill (Tecnal, Piracicaba City, São Paulo State, Brazil), while the faecal samples were sieved at a size of 3 mm, stored in labelled plastic jars with lids and subsequently subjected to analysis.

Faecal production was estimated using indigestible NDF (iNDF) *in situ* as an internal indicator. For this purpose, triplicate samples (800 mg) of feed, faeces and refusal were placed in polypropylene polymer bags (non-woven) incubated in young, rumen-fistulated bulls for 240 h (Casali *et al*., 2008). Thereafter, the residues of incubation were removed, washed until the water became transparent and dried in a forced-ventilation enclosure at 55 °C for 72 h. After drying, the samples were analysed for NDF content according to the methodology of Van Soest *et al*. (1991). To estimate faecal production (kg DM/d), the total amount of the indicator ingested was divided by the indicator concentration in the faeces.

The digestibility coefficients (DCs) of DM, CP, EE, NDF and NFC were calculated using the following equation:

$$DC = \frac{\text{kg of the portion ingested} - \text{kg of the portion excreted}}{\text{kg of the portion ingested}}$$

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Table 3. Feed intake and apparent digestibility coefficient of Nellore bulls fed different levels of palm kernel cake originating from biodiesel production

	Palm kernel cake g/kg (DM basis)					P value*	
Item	0	70	140	210	SEM	Linear	Quadratic
Daily feed intake (kg/day)							
Dry matter (DMI)	10.2	10.8	9.1	8.2	0.47	0.001	0.171
Neutral detergent fibre	2.1	2.7	2.5	2.4	0.18	0.054	0.015
Crude protein	1.29	1.45	1.17	0.98	0.082	0.001	0.026
Ether extract	0.27	0.42	0.40	0.42	0.024	0.001	0.004
Non-fibre carbohydrates	4.0	4.5	2.9	2.3	0.18	<0.001	0.404
Digestibility coefficient							
Dry matter	0.658	0.621	0.614	0.601	0.019	0.054	0.530
Crude protein	0.673	0.644	0.637	0.613	0.023	0.083	0.916
Ether extract	0.701	0.719	0.823	0.854	0.024	<0.001	0.820
Neutral detergent fibre	0.618	0.671	0.613	0.633	0.025	0.915	0.509
Non-fibrous carbohydrate	0.741	0.658	0.667	0618	0.027	0.742	0.653

DM, dry matter; DMI, dry matter intake; SEM, standard error of mean
*Significant at ⩽0.05; $P = 0.05–0.10$ is a trend.

The animals were weighed at the beginning and end of the experiment, after a 16-h solid-food fast. The ADG was computed as the difference between the final and initial BW of each animal divided by the total days of the experiment. The gain : feed ratio (kg/kg) was obtained by dividing ADG by dry matter intake (DMI).

Ingestive behaviour

Individual observations of the animals were conducted every 28 days for 24 h (beginning at 09.00 h, after the diet was offered) in intervals of 5 min to evaluate time spent eating, ruminating and idling in min/day according to the method of Johnson and Combs (1991). Data on each animal's behavioural activities were recorded by two trained observers, who were positioned to interfere as little as possible with the animals' behaviour. Observers took turns every 3 h, and night-time observations were conducted with artificial lighting. The time and number of chews for each ruminal bolus per animal were recorded (total chewing time min/day). In addition, the eating (ER) and rumination rates (RR) based on DM (g DM/h) and NDF (g NDF/h) were calculated as described previously (Burger *et al*., 2000). The results for the feeding behaviour parameters were obtained using the following equations:

$$\mathrm{ER_{DM}} = \frac{\mathrm{DMI}}{\mathrm{FT}}$$

$$\mathrm{RR_{DM}} = \frac{\mathrm{DMI}}{\mathrm{RT}}$$

$$\mathrm{FR_{NDF}} = \frac{\mathrm{NDFI}}{\mathrm{RT}}$$

where $\mathrm{ER_{DM}}$ = eating rates of DM (g DM ingested/h); FT = feed time (h/d); $\mathrm{RR_{DM}}$ = rumination rate of DM (g of ruminated DM/h); RT = rumination time; $\mathrm{FR_{NDF}}$ = frequency of rumination of NDF (g of ruminated DM/h); NDFI = neutral detergent fibre indigestible; RT = rumination time (h/d).

Slaughter and carcass assessment

At the end of the 84-day feeding trial, all animals were slaughtered (after a 16-h fast). The hot carcass weight (HCW) and hot carcass yield (kg total carcass weight/kg final BW) were determined directly after slaughter. The other carcass characteristics evaluated were as follows: subcutaneous fat thickness over the 12th rib and *longissimus* muscle areaLMA (obtained after chilling for 24 h at 2 °C). The carcass conformation and subjective scores of meat marbling, texture and colour (Müller, 1987) were also evaluated.

Statistical analyses

The experimental design was completely randomized, with four treatments and eight replicates per treatment. The following statistical model was used:

$$Y_{ij} = \mu + si + e_{ij}$$

where Y_{ij} = observed value; μ = overall mean; si = effect of palm kernel cake levels; and e_{ij} = effect of experimental error.

The data were subjected to analysis of variance through the PROC GLM command of the SAS statistical package (SAS version, 9.1, 2003), and the means were subjected to regression analysis through the PROC REG command of the SAS® (9.1) statistical package (SAS University Edition). The initial weight was considered as a covariate in the statistical model. Significance was declared when $P \leqslant 0.05$ and trends were discussed at $0.05 < P < 0.10$.

Results

Dry matter ($P = 0.001$), CP ($P = 0.002$) and NFC ($P < 0.001$) intake decreased linearly, and EE ($P = 0.001$) intake increased

Table 4. Performance data of bulls fed different levels of palm kernel cake originating from biodiesel production

	Palm kernel cake g/kg (DM basis)					*P* value*	
Variable	0	70	140	210	SEM	Linear	Quadratic
Initial BW (kg)	431	431	432	435	9.2	0.753	0.854
Final BW (kg)	547	537	520	524	14.7	0.014	0.582
ADG (kg/day)	1.4	1.3	1.1	1.1	0.11	0.020	0.552
Gain : feed ratio (kg/kg)	0.13	0.12	0.11	0.13	0.008	0.494	0.058

DM, dry matter; SEM, standard error of the mean; BW, body weight; ADG, average daily gain
*Significant at ⩽0.05; $P = 0.05–0.10$ is a trend.

linearly, whereas NDF ($P = 0.015$) intake exhibited a quadratic increase (Regression equation $y = -3E\text{-}05x^2 + 0.0081x + 2.173$ and determination coefficient $R^2 = 0.86$) with maximum inclusion of 140 g/kg palm kernel cake in the bulls' diet (Table 3). The apparent total tract digestibility of DM ($P = 0.054$) and CP ($P = 0.083$) tended to be reduced linearly with increasing inclusion levels of palm kernel cake. In contrast, EE digestibility ($P < 0.001$) was associated positively with the level of palm kernel cake in the diet. Increasing the levels of palm kernel cake in the diets resulted in a linear decrease in ADG ($P = 0.020$) and final BW ($P = 0.014$) (Table 4) and a trend for the gain : feed ratio to decrease quadratically in the Nellore bulls.

There was no effect of palm kernel cake inclusion on the time spent (min/day) eating ($P = 0.761$) or idling ($P = 0.108$), or the total chewing time ($P = 0.109$) (Table 5) of Nellore bulls. There was a trend towards a linear decrease in the time spent (min/day) on rumination ($P = 0.060$) with palm kernel cake inclusion. There was a linear decrease ($P = 0.011$) of the DM eating rate (g DM ingested/h) and DM rumination rate ($P < 0.001$; g DM ruminated/h) with the inclusion of palm kernel cake in the bulls' diet. However, there were no differences in NDF rumination ($P = 0.114$) and eating ($P = 0.124$) rate (g NDF/h) with the inclusion of palm kernel cake.

The hot carcass yield was not influenced ($P = 0.337$) by the inclusion level of palm kernel cake, but the carcass weight ($P = 0.042$) decreased linearly (Table 6). Subcutaneous fat thickness ($P = 0.722$), LMA ($P = 0.249$), colour index ($P = 0.305$), texture ($P = 0.216$) and marbling ($P = 0.525$) did not differ among the bulls fed the evaluated diets.

Discussion

The observed decrease in DMI could be explained by the increases in ADF (570 g/kg) and ADL (550 g/kg) contents of the diets: a tendency for decreases in the digestibility of DM (associated with increased ADF concentration) and CP was also found. These changes could have influenced protein and energy availability in animals fed palm kernel cake (Gonzaga *et al*., 2015; Oliveira *et al*., 2015*a*). In addition, with the concurrent decreases in NFC intake and contents in the diets, along with an increase in EE intake, it is possible that there was a reduction of energy available in the rumen for microbial protein synthesis, since fat is not a source of energy used by microorganisms (Visoná-Oliveira *et al*., 2015). This situation could occur under substitution of feeds that are rich in non-structural carbohydrates with co-products rich in ADF and ADL, thereby reducing nitrogen retention by rumen microorganisms for microbial protein synthesis.

The apparent total tract digestibility of DM and CP tended to be reduced (both by 9%) with increasing levels of palm kernel cake, while EE digestibility increased (by 18%). The greater digestibility of EE and lower DM digestibility can be explained by the increase in EE intake. The increases in the content of neutral detergent insoluble protein and especially acid detergent insoluble protein caused a decrease in the CP digestibility of the diets, compromising weight gain.

The greater EE intake observed was a result of the increased palm oil lipids provided by palm kernel cake inclusion (3.2–6.1 g/kg in the composition of the diets with and without palm kernel cake, respectively). It is important to emphasize that the EE levels in the diets were below 8 g/kg, which is considered the maximum level of lipids (NRC, 2000) to avoid a reduction in DMI. Thus, the inclusion of lipids, such as those present in palm kernel cake, does not supply energy to the rumen, as there is no lipid fermentation in the rumen. Furthermore, the animal can still use lipids as an energy source, and meat and milk quality can be improved, which is an additional benefit of using diets with oil and cakes for ruminants (Abubakr *et al*., 2015; Santana Filho *et al*., 2015). When there is an increase in EE intake, coating of fibre generally occurs, causing a reduction in NDF digestibility (Oliveira *et al*., 2015*a*), which was not observed in the current study. In addition, the unsaturated fatty acids present in oil cake exert toxic effects directly on ruminal microorganisms, in addition to reducing the availability of cations by combining them with fatty acids, thereby decreasing degradability (Palmquist, 1991). According to Van Soest (1994), one of the factors that may affect digestibility is the degree of grinding, due to the faster rate of passage of digesta through the digestive tract. The fact that palm kernel cake was offered in ground form may have compensated for the oil-induced effects on fibre digestibility, with the final outcome being no effect on NDF digestibility. Regarding ingestive behavioural characteristics, the absence of an effect on eating, rumination and idling time (min/day) is an indicator that the fibre present in palm kernel cake in the format supplied had no impact.

There was a decrease in eating and rumination rates, which was associated with the reduction of DMI caused by increases in the ADF and ADL contents of the diets, which stimulated rumination activity (Huhtanen *et al*., 2016); however, these conditions limited intake due to a longer retention time of feed in the rumen (Van Soest, 1994), as observed in other studies involving palm kernel cake (Pimentel *et al*., 2015; Santos *et al*., 2016).

The linear decreases in final BW (50 g/kg) and ADG (230 g/kg) with increased inclusion of palm kernel cake were a result of the reduction of the intake of DM (200 g/kg) and CP (250 g/kg) and a tendency for decreases in DM (100 g/kg) and CP (100 g/kg) digestibility. As a result, there was a lower supply of

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Table 5. Ingestive behaviour data of bulls fed different levels of palm kernel cake originating from biodiesel production

	Palm kernel cake g/kg (DM basis)					P value*	
Item	0	70	140	210	SEM	Linear	Quadratic
Time spent (min/day)							
Eating	193	211	197	203	6.0	0.761	0.619
Rumination	375	394	440	426	11.8	0.060	0.472
Idling[a]	872	833	804	808	14.8	0.108	0.465
Total chewing time[b]	568	606	638	630	28.8	0.109	0.443
Eating rate							
g DM/h	1268	1228	1105	965	11.5	0.011	0.468
g NDF/h	266	304	308	281	10.6	0.124	0.005
Rumination rate							
g DM/h	653	658	495	460	12.9	<0.001	0.351
g NDF/h	137	163	138	134	14.9	0.114	0.381

DM, dry matter; SEM, standard error of the mean
[a]Idling time includes all other activities that are not eating or rumination
[b]Total chewing time includes eating and rumination activities
*Significant at ⩽0.05. P = 0.05–0.10 is a trend.

Table 6. Carcass traits and quality attributes of the *longissimus dorsi* muscle of Nellore bulls fed different levels of palm kernel cake originating from biodiesel production

	Palm kernel cake g/kg (DM basis)					P value*	
Variable	0	70	140	210	SEM	Linear	Quadratic
Hot carcass weight (kg)	311	310	300	297	8.5	0.042	0.853
Hot carcass yield (g/kg)	569	565	569	560	0.5	0.371	0.739
SFT (mm)	2.9	4.6	2.6	3.2	0.64	0.722	0.418
LMA (cm^2)	76	75	84	79	3.3	0.249	0.495
Colour[a]	3.6	4.0	3.5	3.5	0.18	0.305	0.325
Texture[a]	4.1	4.0	3.9	4.0	0.12	0.216	0.168
Marbling[a]	5.8	8.1	5.4	5.9	0.81	0.525	0.266

DM, dry matter; SEM, standard error of the mean; SFT, subcutaneous fat thickness; LMA, longissimus muscle area
[a]Scale of assessments for colour, texture and marbling according to Müller (1987): ranging from 1 to 5 to colour and texture and from 1 to 18 for marbling (colour = 1: dark, 3: slightly dark red and 5: red; texture = 1: very thick, 3: slightly thick and 5: very fine; marbling = 1: trace minus, 5: light, 8: small, 11: medium, 14: moderate, 17: abundant).
*Significant at ⩽0.05. P = 0.05–0.10 is a trend.

analytical fractions, such as DM and CP, which interferes with performance. As observed above, the energy availability in the form of NFC decreased with increasing palm kernel cake levels in the experimental diets, which was reflected in ADG. When the cake was substituted for a portion of maize in the diet, there was a decrease in the rapidly fermentable carbohydrate content of the diets, whereas the estimated ME and DE concentrations in the diets were not altered. In fact, these values were almost equivalent to those of the control diet, which contained greater amounts of NFC. It is possible to infer that palm kernel cake was an ingredient that, when included as a lipid source, maintained the energy levels of the diets, though not at high enough levels to compensate for the energy lost through the reduction on DM intake and digestibility; therefore, both ME and metabolizable protein were limited compared with the control diet (Ferreira *et al*., 2012).

The addition of co-products to feedlot rations has been used to improve animal performance and, consequently, reduce the time to slaughter and increase the efficiency of the production system (Abubakr *et al*., 2015). However, many factors intrinsic to the use and quality of co-products in ruminant animal diets interfere with intake regulation in addition to the digestibility of these alternative sources (Van Soest, 1994). Greater inclusion of palm kernel cake (140 or 210 g/kg) was reflected in lower gains (1.05 and 1.06, respectively), possibly because the cake protein exhibits less availability of amino acids in the rumen and no availability of amino acids in the intestine. The cake contains a significant amount of protein in the form of ADIP, which reduces the availability of amino acids in the rumen for intestinal absorption and influences the animals' performance (Van Soest, 1994).

The decrease in intake by animals with higher palm kernel cake inclusion reduced HCW by approximately 15 kg. For each

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10 g increase in the inclusion level of palm kernel cake, there was a 272 g decrease in carcass weight. The decrease in HCW with the inclusion of palm kernel cake is relevant from a market point of view, where prices are sometimes negotiated based on this parameter, and a decreased HCW can therefore result in lower profit margins for the producer.

Regarding qualitative carcass characteristics, even though carcass weight decreased in animals consuming diets with a greater proportion of palm kernel cake, subcutaneous fat thickness and the LMA were not affected, indicating similar development of the studied animals.

Colour, texture and marbling characteristics did not differ with the inclusion of palm kernel cake. The average colour score recorded in the present study was 3.65, which corresponded to 'slightly dark red' according to the classification proposed by Müller (1987), and this colour is generally well accepted by the consumer. The texture of the LMA received an average score of 4.00 points, corresponding to a fine texture, indicating that the meat surface granulation presented features that classify it as a good quality product. The meat of the bulls used in the present study exhibited marbling scores ranging from slightly low to low according to the scale proposed by Müller (1987).

In conclusion, the use of palm kernel cake above 70 g/kg in finishing cattle diets is not recommended because a longer finishing period will be needed for the bulls to reach their target slaughter weight, or a market for lighter carcasses will have to be found. However, qualitative carcass attributes were not affected by the use of palm kernel cake. In the decision to use palm kernel cake above 70 g/kg, producers should take into consideration the profitability arising from the inclusion of palm kernel cake, which is used to reduce the amounts of expensive ingredients in diets (maize and soybean), as well as the possible need to maintain, rather than gain animal weight. The strategic use of palm kernel cake associated with other feed concentrates can be helpful for obtaining animals with similar carcass quality. However, the use of palm kernel cake as an ingredient will depend on the harvest period, during which there is a reduction in the cost of purchasing palm kernel cake.

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Ethical standards. All animal use procedures followed the guidelines recommended by the Animal Care and Use Committee of the institution (Protocol 17/2014).

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