South African Journal of Animal Science 2023, 53 (No. 4)

Short communication

Carcass traits and meat quality of steers fed palm kernel cake as a replacement for grain sorghum

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(Submitted 4 May 2022; Accepted 13 March 2023; Published 26 August 2023)

Abstract

The objective of this study was to evaluate the effect of replacing grain sorghum (GS) with palm kernel cake (PKC) on the performance, carcass traits and meat quality of feedlot steers fed high-grain diets. Forty male ½ Holstein × ½ Nellore steers with an initial weight of 331.1 ± 36.2 kg, at 24 ± 2 months of age, were housed in group stalls (10 cattle/stall) where they received diets containing 0, 80, 160, or 240 g/kg PKC on a dietary dry matter basis. After 126 days, the animals were slaughtered and their carcass and meat evaluated. The replacement of GS with PKC did not influence empty body weight, carcass weight, carcass length, or carcass yield. However, the thickness of subcutaneous fat in the carcass decreased with the replacement of GS with PKC. The meat pH increased linearly, whereas there were no changes in cooking loss, shear force, lightness (L*), and fat or cholesterol contents in the meat of the steers. Partial replacement (41,57%) of GS with PKC is recommended, with an inclusion of up to 240 g/kg PKC in high-grain diets for steers.

Keywords: biodiesel by-products; cholesterol; *Elaeis guineensis*; fat thickness; shear force
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Brazil is among the largest beef producers and exporters on the planet. In 2019, Brazilian beef production reached 10.20 million tons of carcass equivalent (FAO, 2021). Although the country is the world leader in beef exports, the product is still rated as low-quality, which is mainly because the animals are finished on pasture (Ferraz & Felício, 2010; Lobato *et al*., 2014, Malafaia *et al*., 2021).

Finishing animals in the feedlot allows for greater uniformity in meat cuts, meat quality, and carcass fatness, which has a positive impact on traits of economic interest such as the marbling, colour, and tenderness of meat (Freitas *et al*., 2014; Pacheco *et al*., 2014; Kenny *et al*., 2018). Nonetheless, feedlot finishing is a costlier system due mostly to the need for increasing the energy density and protein content of the diets (Koknaroglu *et al*., 2005).

Grain corn and sorghum are the conventional sources of energy used in the feedlot finishing of cattle in Brazil (Silvestre & Millen, 2021). However, market prices have made it difficult to use these starch sources in cattle diets and forced nutritionists to adopt alternative ingredients such as byproducts. In this context, byproducts generated in the biodiesel industry, such as palm kernel cake (PKC), have great potential for use in the diet of feedlot cattle due to their lipid (54 g/kg) and protein (196 g/kg) contents (Lisboa *et al*., 2021). In addition, the high neutral detergent fibre levels (601 g/kg) in PKC may improve the ruminal health of feedlot cattle on high-grain diets (Santos *et al*., 2019).

Studies have shown that the inclusion of PKC consistently reduces production performance, weight, and carcass fat in lambs and goats (Santos *et al*., 2017; Rodrigues *et al*., 2021; Silva *et al*.,

URL: http://www.sasas.co.za
ISSN 0375-1589 (print), ISSN 2221-4062 (online)
Publisher: South African Society for Animal Science
http://dx.doi.org/10.4314/sajas.v53i4.06

2021), but does not seem to interfere with the physicochemical traits of goat meat (Ribeiro *et al*., 2018). In feedlot cattle, preliminary studies (Santana Filho *et al*., 2016; Cruz *et al*., 2018) have showed a linear decrease in performance and carcass weight and no changes in the physicochemical traits of meat in response to the dietary inclusion of PKC. In this respect, there is little evidence in the literature about the use of PKC for feedlot cattle, especially in high-grain diets, and its effects on the carcass and meat of these animals.

The hypothesis of this study was that the concentrations of inclusion of palm kernel cake up to 240 g/kg in the diet of confined, crossbred cattle could improve the carcass traits and meat quality of these animals. This study thus proposed to investigate the effects of replacing grain sorghum with palm kernel cake on the carcass traits and meat quality of feedlot steers fed high-grain diets.

The present study was approved by the Ethics Committee on Animal Use at the State University of Southwest Bahia (approval no. 45/2013). Forty uncastrated, half-blood, Holstein × Zebu crossbred cattle at an average age of 24 ± 2 months, with an initial average weight of 331.1 ± 36.2 kg, were housed in group stalls (10 animals/stall) with a usable area of 100 m^2 (10 × 10 m), with 50 m^2 of cement floor and 50 m^2 partially covered. The stalls were equipped with covered concrete feeders (10 linear meters) and drinkers of 250-L capacity. The animals were weighed, identified with plastic eartags, and dewormed (Abamectin-1% - Abmic® Microsules). After weighing, they were randomly distributed into four treatments in a completely randomized design with ten replicates. The treatments consisted of diets containing 0 (control), 80, 160, or 240 g/kg of PKC on a dietary dry matter (DM) basis (Table 1).

Table 1. Feed ingredients and chemical composition of the experimental diets (g/kg DM)

Ingredient	**Palm kernel cake, g/kg DM**			
	0	**80**	**160**	**240**
Sugarcane bagasse	200.0	200.0	200.0	200.0
Cottonseed	200.0	200.0	200.0	200.0
Ground sorghum	577.3	497.3	417.3	337.3
Palm kernel cake	0	80.0	160.0	240.0
Sodium bicarbonate	10	10	10	10
Limestone	7.7	7.7	7.7	7.7
Mineral mix[1]	5.0	5.0	5.0	5.0
Chemical composition				
Dry matter, g/kg[2]	823.8	824.7	825.5	826.4
Mineral matter, g/kg	53.2	53.8	54.4	55.0
Crude protein, g/kg	99.9	104.4	109.0	113.5
Ether extract, g/kg	55.2	60.6	66.0	71.4
NDFap[3], g/kg	314.2	357.5	400.8	444.0
ADF[4], g/kg	224.1	256.4	288.7	321.0
Non-fibre carbohydrates, g/kg	476.8	422.9	369.1	315.2
Total digestible nutrients, g/kg	601.2	596.3	573.6	571.6
ME, MJ ME/kg DM[5]	11.08	11.04	10.58	10.54

[1]Composition: calcium 140 g, phosphorus 65 g, sodium 148 g, magnesium 5 g, sulphur 12 g, cobalt 107 mg, copper 1,550 mg, iodine 150 mg, manganese 1,400 mg, nickel 30 mg, selenium 18 mg, zinc 4,500 mg, 1,120 mg, fluorine (maximum) 650 mg
[2]g/kg fresh matter
[3]neutral detergent fibre corrections for protein and ash
[4]acid detergent fibre
[5]metabolizable energy

For information on feed composition, animal management during the feedlot period and estimates of nutrient intake and digestibility and animal performance, see Lisboa *et al*. (2021).

After 126 days, the animals were weighed without previous fasting. Subsequently, they were deprived of solid and liquid feed for 12 h to determine the final body weight (FBW) and the empty body weight (EBW). After fasting, the animals were slaughtered, skinned, and eviscerated in a commercial slaughterhouse in Itapetinga - BA, Brazil, following current law (Brasil, 2000). The carcass of each animal was sawn lengthwise along the sternum and spine, producing two similar halves, which were weighed to determine the hot carcass weight (HCW). Hot carcass yield (HCY) was calculated as HCW/EBW (Gomes *et al*., 2021). Gain yield (GY) was calculated using the following equation:

GY (%) = (Hot carcass weight - Initial carcass weight) / (Final body weight - Initial body weight) * 100 (1)

Carcass gain (GC), in turn, was calculated using the following equation:
GC (kg) = (Gain yield × Average daily gain)/100 (2)

The right half-carcasses were identified and stored in a cold chamber, where they were kept at 4 °C for 24 h. After this period, the carcasses were measured to determine carcass and leg lengths and beef round thickness. Carcass conformation was evaluated according to the scale suggested by Gomes *et al*. (2021).

Ribeye area was measured on the right side of the carcass by making a cross-section between the 12th and 13th ribs and exposing the *longissimus lumborum* muscle. Then, its outline was traced on parchment paper and the area was later measured with a planimeter. Subcutaneous fat thickness was determined as the average of three measurements at equidistant points, using a precision calliper, in the region of the section between the 12th and 13th ribs. 'Ratio', a measurement that characterizes the ratio between the height and width of the *longissimus lumborum* muscle (obtained using a graduated ruler), was also determined.

A sample of the *Longissimus dorsi* muscle was dissected between the 10th and 13th ribs in each right half-carcass, wrapped in film, placed in high-density plastic bags, and covered with aluminium foil. Muscle samples were stored in a freezer at -10 ºC for 60 d until laboratory analysis. To determine the physicochemical parameters in the logical order of analysis, the colour was first determined, followed by cooking loss and shear force. In parallel, water-holding capacity and the ionic potential of hydrogen were measured, following the methodologies described by Ramos & Gomide (2017).

The pH was determined in triplicate, using a Quimis 0400MT benchtop pH meter. For chemical analysis, the samples were thawed at room temperature, the subcutaneous fat was removed, and the muscle was lyophilized to determine the moisture, ash, and crude protein contents, following the methodology proposed in AOAC (2000). Total lipids were determined using a method adapted from Bligh & Dyer (1959). Total cholesterol was extracted according to the method described by Al-Hasani *et al*. (1993).

The data were evaluated according to the following statistical model:

$$Y_{ij} = \mu + T_i + B(X_{ij}–X) + e_{ij}, \quad (3)$$

where Y_{ij} = experimental response measured in treatment i and replicate j; µ = overall constant; T_i = effect of treatment i, where i = 0, 80, 160, and 240; $B(X_{ij} – X)$ = effect of covariate (initial weight); and e_{ij} = random error associated with each observation. The data were subjected to analyses of variance and regression using the GLM and REG procedures of Statistical Analyses System software.

The replacement of GS with PKC caused the metabolizable energy intake of the animals to decrease linearly (P <0.05) but did not influence (P >0.05) digestible protein intake or final body weight (Table 2).

Empty body weight (474.3 ± 51.4 kg), carcass weight (242.2 ± 31.67 kg), carcass gain (0.70 ± 0.15 kg), carcass yield (51.01 ± 2.01%), carcass length (129.1 ± 5.06 cm), and leg length (72.4 ± 11.37 cm) did not change (P >0.05) in response to the replacement of sorghum with PKC in the steers' diet. Subcutaneous fat thickness decreased linearly (P <0.05).

Whereas the meat pH increased linearly (P <0.05), there were no changes in cooking loss (32.42 ± 42.35%), water-holding capacity (69.21 ±1.73%), shear force (3.35 ± 0.32 kgF), or the objective colour parameters of the meat (Table 3). The replacement of GS with PKC did not influence (P >0.05) the moisture (72.68 ± 1.03%), fat (3.42 ± 0.27%), or cholesterol (40.03 ± 2.98 mg/100 g) contents of the meat (*Longissimus*).

Table 2. Performance and carcass traits of steers fed palm kernel cake as a replacement for grain sorghum

	Palm kernel cake (g/kg DM)				SEM[1]	P-value[2]	
	0	80	160	240		L	Q
Metabolizable energy intake (MCal/day)	18.59	19.37	17.04	15.67	3.71	0.01[a]	0.34
Digestible protein intake (g/day)	481.4	555.1	487.2	487.2	58.81	0.69	0.47
Final body weight (kg)	473.4	494.0	487.9	484.7	11.04	0.71	0.48
Empty body weight (kg)	462.7	482.0	477.3	475.2	10.83	0.65	0.51
Hot carcass weight (kg)	240.7	243.9	244.8	240.2	13.07	0.97	0.68
Hot carcass yield (%)	51.82	50.45	51.25	50.54	3.95	0.32	0.51
Gain yield (%)	56.07	51.22	54.36	51.76	11.80	0.27	0.57
Carcass gain (kg/day)	0.741	0.708	0.714	0.626	22.07	0.12	0.56
Arroba (= 15 kg of animal)	16.01	16.26	16.32	16.01	13.07	0.97	0.68
Subcutaneous fat thickness (mm)	3.50	3.41	3.20	3.21	88.7	0.01[b]	0.60
Ribeye area (cm^2)	70.20	71.40	69.80	69.90	9.81	0.82	0.81
'Ratio'	0.45	0.44	0.47	0.49	13.22	0.06	0.73
Carcass conformation	11.20	10.70	11.10	10.70	4.50	0.12	0.75
Leg length (cm)	66.15	73.60	75.20	74.5	15.70	0.10	0.26
Bee round thickness (cm)	26.85	26.85	27.45	26.9	7.18	0.62	0.31
Carcass length (cm)	128.50	129.30	129.20	129.50	3.92	0.68	0.87

[1]Standard deviation of the mean
[2]Significance of P for linear (L) or quadratic (Q) effects.
Regression equation: [a]$\hat{Y}$= 19.331 – 0.1386X. R^2 = 0.76; [b]$\hat{Y}$= 3.49975 – 0.0134831X. R^2 = 0.88

Table 3. Chemical composition and cholesterol content of the *Longissimus dorsi* muscle of steers fed palm kernel cake as a replacement for grain sorghum

	Palm kernel cake (g/kg DM)				SEM[1]	P-value[2]	
	0	80	160	240		L	Q
pH	5.61	5.65	5.78	5.77	0.127	0.02[a]	0.57
Cooking loss, %	34.11	32.70	31.93	30.96	42.35	0.11	0.87
Shear force, kgf/cm^2	3.26	3.29	3.58	3.25	0.319	0.59	0.07
Water-holding capacity (%)	69.84	68.60	69.27	69.15	1.730	0.57	0.31
Lightness (L*)	35.44	39.32	38.21	38.99	5.512	0.22	0.37
Red content (a*)	15.26	15.51	15.56	12.26	2.111	0.99	0.68
Yellow content (b*)	2.97	3.01	2.97	2.86	0.177	0.16	0.21
Moisture (%)	72.99	72.45	72.88	72.41	1.032	0.62	0.09
Ash (%)	1.36	1.48	1.38	1.38	0.231	0.19	0.49
Crude protein (%)	22.07	22.31	22.03	22.03	0.674	0.15	0.06
Total lipids (%)	3.41	3.41	3.33	3.42	0.273	0.22	0.29
Cholesterol (mg/100 g)	39.33	38.89	41.11	40.05	2.980	0.09	0.28

[1]Standard deviation of the mean
[2]Significance of P for linear (L) or quadratic (Q) effects
Regression equation: [a]$\hat{Y}$ = 5.6188 + 0.007475X; R^2 = 0.86

The decrease in metabolizable energy intake did not influence empty body weight. This was possibly because the replacement of the starch from GS with PKC reduced the heat increment of feeding and provided more net energy for gain in the steers that consumed PKC. Additionally, digestible protein intake was similar between the treatment groups. In contrast, Cruz *et al*. (2018) and Santos *et al*. (2019) reported decreases in the crude protein intake and final weight of steers and cull cows, respectively, following the inclusion of PKC in the diet.

Hot carcass weight and carcass gain were not influenced by the inclusion of PKC in the diet, possibly because of the observed similarity in empty body weight between the treatment groups. Hot carcass weight has a strong positive correlation with slaughter weight in cattle (Façanha *et al*., 2014). In addition, the produced carcasses met the standard weight required by the Brazilian domestic market (minimum of 225 kg) for Zebu animals. Gordo *et al*. (2018) recently reported a carcass weight of 272 ± 24.70 kg in animals slaughtered in Brazil.

The average carcass gain observed in this study was compatible with high-grain diets, indicating that even with the inclusion of a byproduct and the removal of part of the starch from the diet, the efficiency of nutrient conversion into carcass was high for Zebu animals (Paulino *et al*., 2013). Benediti *et al*. (2016) also did not observe an effect of replacing corn with crude glycerine on the carcass gain of cattle.

The reduced subcutaneous fat thickness may be attributed to a decreased synthesis of short-chain fatty acids (SCFA) in the cattle rumen induced by the reduced presence of GS in the diet (Gómez *et al*., 2016). Lower levels of SCFA—acetate and butyrate, mainly—in the peripheral circulation result in fewer acetyl units for fatty acid synthesis in subcutaneous adipocytes in cattle (Park *et al*., 2018). Although low by international standards, the average subcutaneous fat thickness found in the present study (3.21–3.50 mm) was considered adequate for Zebu carcasses. Bonin *et al*. (2021), for instance, reported an average fat thickness of 3.59 mm in the carcasses of animals slaughtered in Brazil.

It is possible that the lower presence of GS in the diet (resulting from its replacement with PKC) impaired the synthesis of rumen propionate (Lage *et al*., 2017). This SCFA is involved in the processes of hepatic gluconeogenesis and hepatic and muscle glycogenesis (Gardner *et al*., 2014). Therefore, the animals fed PKC might have produced less rumen propionate, which led to lower muscle glycogen stores and, consequently, a higher final pH of their meat.

Despite the observed decrease in the final pH of the meat, the physicochemical parameters of cooking loss and water-holding capacity were not influenced. We suggest that the increase in the final pH of the meat (0.056 at each 80 g/kg PKC) of the animals fed PKC was not sufficient to elicit consistent changes in water retention within the myofibrillar proteins (Peace *et al*., 2011).

Water retention, in turn, influences lightness (Rosa *et al*., 2016) and, together with other objective colour measurements (a* and b*), these two variables were similar between the treatment groups. Besides the pH, the similar age and physiological stage of the animals likely contributed to the observed proximity of objective colour parameters (Hughes *et al*., 2014). Oliveira *et al*. (2020) evaluated the meat of feedlot-finished Nellore cattle and found L*, a*, and b* values of 34.38, 17.92, and 9.9, respectively. In addition to the colour, the tenderness of meat is also markedly influenced by age, particularly in terms of collagen solubility (Pacheco *et al*., 2020). Thus, the lack of effects of PKC inclusion on tenderness (shear force) is due to the similar age of the animals at slaughter. Santana Filho *et al*. (2016) also did not observe an effect of including 210 g/kg PKC on the cooking loss, water-holding capacity, shear force, or colour parameters of beef.

Even with the increase in the EE content of the diet provided by the inclusion of PKC, the steers produced meat with a low fat content (3.42% EE) (Casperson *et al*., 2020). This low intramuscular fat content is possibly due to the fact that the experimental animals —uncastrated Nellore slaughtered at 485 kg—had not yet reached mature weight for intact Nellore males (Silva *et al*., 2013). Despite the increase in the EE content of the experimental diets, the cholesterol content of the steers' meat was not altered by the dietary inclusion of PKC, possibly because the endogenous synthesis of cholesterol depends more on acetyl units. Silva *et al*. (2021) also reported no influence of the inclusion of licuri cake (*Syagrus coronate*) in the diet on the proximate composition of the meat of steers.

The partial replacement (41,57%) of grain sorghum with palm kernel cake in high-grain diets for feedlot steers reduces the thickness of subcutaneous fat in their carcass but does not interfere with carcass weight or meat tenderness, colour, and composition. The inclusion of 240 g/kg palm kernel cake in high-grain diets for feedlot steers is recommended.

Acknowledgements

Thanks are due to the Coordination for the Improvement of Higher Education Personnel (CAPES) for the Master's fellowship grant.

Authors' Contributions

M. M. Lisboa (0000-0002-0278-940X), F. F. Silva (0000-0002-2837-1570), G. G. P. Carvalho (0000-0002-4108-6782), J. W. D. Silva (0000-0002-2695-8255), A. P. G. Silva (0000-0002-4544-0339), V. M. Carvalho (0000-0002-2875-7799), L. V. Santos (0000-0002-3825-2292), M. C. Santos (0000-0001-5953-1664), D. M. Lima Júnior (0000-0002-1154-8579), R. R. Silva (0000-0003-1059-3308). MML, FFS, and GGPC participated in designing the study, laboratory analysis, and manuscript writing; JWDS, APGS, and VMC, involvement in drafting and revising the manuscript for important intellectual content; LVS and MCS, data analysis and interpretation; DMLJ, RRS, contributions to the acquisition, analysis, and interpretation of data.

Conflict of interest

The authors declare that they have no conflict of interest.

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