Beef quality of Nellore steers fed dried or rehydrated and ensiled corn or sorghum grains

Calidad de la carne de Ganado Nelore alimentado con grano de maíz o sorgo seco o rehidratado y ensilado

Qualidade de carne de bovinos Nelore alimentados com grãos de milho ou sorgo seco ou reidratado e ensilado

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Abstract

Background: Rehydration of grains, such as corn and sorghum, is used to increase nutrient absorption. However, the effect of this practice on meat quality is poorly understood. **Objective:** To evaluate the effects of type of grain and processing on the meat quality of Nellore steers in a feedlot. **Methods:** Twenty-four non-castrated Nellore steers $(270 \pm 53 \text{ kg} \text{ initial body} weight)$ were distributed in a completely randomized 2×2 factorial design, with six replicates. The first factor was cereal type (corn or sorghum), and the second was the grain processing (dry or rehydrated and ensiled). The diets were composed of 30% corn silage and 70% concentrate. Sixty days before the beginning of the experiment, corn and sorghum grains were rehydrated and ensiled. The animals were slaughtered after 140 days of confinement. Meat quality analyses were determined in samples of fresh and aged meat (7 days) from the *Longissimus lumborum* muscle. **Results:** no difference between treatments was observed for carcass pH and L* (lightness), a* (redness), and b* (yellowness) values, shear force, thawing and cooking losses, and chemical composition of meat (p>0.05). The b* (yellowness) value of subcutaneous fat was higher in steers fed corn, regardless of grain processing (p=0.03). Sarcomere length was higher in aged meat of steers fed sorghum, regardless of processing method does not affect beef quality; however, grain type can affect subcutaneous fat color and sarcomere length of aged beef.

Keywords: *beef; bovine; cattle; corn; ensiled grain; grain; maize; marbling; meat color; meat quality; Nellore; sarcomere; silage; sorghum; subcutaneous fat; zebu.*

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Resumen

Antecedentes: La rehidratación de granos, tales como maíz y sorgo, se usa para aprovechar mejor sus nutrientes. Sin embargo, es poco conocido el efecto de esta práctica sobre la calidad de la carne. Objetivo: Evaluar los efectos del tipo de cereal y su procesamiento sobre la calidad de carne de toretes Nelore en confinamiento. Métodos: Veinticuatro novillos Nelore enteros con un peso promedio inicial de 270 ± 53 kg, se distribuyeron en un diseño factorial 2×2 completamente aleatorizado (n=6). El primer factor fue el tipo de cereal (maíz o sorgo) y el segundo fue su procesamiento (seco o rehidratado y ensilado). Las dietas estuvieron compuestas por 28,44% de ensilaje de maíz y 71,56% de concentrado. Sesenta días antes de iniciar el experimento, los granos de maíz y sorgo se rehidrataron y ensilaron. Los animales se sacrificaron después de 140 días de confinamiento. La calidad de la carne se determinó en muestras de carne fresca y madurada (7 días) obtenidas del músculo *Longissimus lumborum*. **Resultados:** No hubo diferencias entre tratamientos para el pH de las canales, ni para los valores de color (L* "luminosidad", a* "intensidad de rojo" y b* "intensidad de amarillo"), fuerza de corte, composición química, o pérdidas de agua por descongelamiento o cocción (p>0,05). El valor de b* de la grasa subcutánea fue mayor en los novillos alimentados con maíz, independientemente del tipo de procesamiento (p=0,03). La longitud de sarcómero fue más alto en la carne madurada de novillos alimentados con sorgo, sin importar el método de procesamiento (p=0,01). **Conclusiones:** El método de procesamiento del grano no afecta la calidad de la carne; sin embargo, el tipo de cereal afecta el color de la grasa subcutánea y la longitud del sarcómero de la carne madurada.

Palabras clave: bovino; calidad de carne; carne; cebú; cereal; color de la carne; ensilado; ensilaje; ganado; grano; grano ensilado; grasa subcutánea; maíz; marmoreo; Nelore; sarcómero; sorgo.

Resumo

Antecedentes: A reidratação de grãos, como milho e sorgo, tem sido usada para aumentar a utilização de seus nutrientes. Contudo, o efeito dessa prática na qualidade da carne é pouco compreendido. Objetivo: Avaliar os efeitos do tipo de grão de cereais e seu processamento sobre a qualidade da carne de bovinos confinados. Métodos: Vinte e quatro bovinos Nelore não castrados, com peso corporal médio inicial de 270 ± 53 kg foram distribuídos em delineamento inteiramente casualizado, fatorial 2×2, com seis repetições. O primeiro fator foi o tipo de grão de cereal no concentrado (milho ou sorgo), e o segundo foi o processamento destes grãos (seco ou reidratado e ensilado). As dietas foram compostas por 28,44% de silagem de milho e 71,56% de concentrado. Sessenta dias antes do início do experimento, os grãos de milho e sorgo foram reidratados e ensilados. Os animais foram abatidos após 140 dias de confinamento. As análises de qualidade da carne foram determinadas em amostras não maturadas e maturadas (7 dias) obtidas do músculo Longissimus lumborum. Resultados: Não houve diferenças significativas (p>0,05) entre os tratamentos para pH da carcaça e L* (luminosidade), a* (intensidade de vermelho), b* (intensidade de amarelo), força de cisalhamento, perdas por descongelamento, perdas por cocção, perdas totais e composição química da carne. O valor de b* da gordura subcutânea foi maior (p=0,03) em bovinos alimentados com dietas contendo grãos de milho, independentemente do tipo de processamento. O comprimento de sarcômero foi maior na carne maturada de novilhos alimentados com sorgo, independente do método de processamento (p=0,01). Conclusões: O método de processamento dos grãos não afetou a qualidade da carne bovina, no entanto, a cor da gordura subcutânea e o comprimento de sarcômero da carne maturada foram afetados pelo tipo de grão.

Palavras-chave: bovino; color da carne; gado; gordura subcutânea; grão; grão ensilado; marmoreio; milho; Nelore; qualidade de carne; sarcômero; sorgo; zebuíno.

Introduction

Brazil is the largest beef exporter (USDA, 2018). Corn and sorghum grains are the main starch sources used for Brazilian steers in feedlots (Oliveira and Millen, 2014). However, both cereals have a strong protein matrix around the starch granules, limiting ruminal and intestinal digestion. This problem is aggravated in Brazil, where most corn hybrids have a hard endosperm, rich in protein matrix (Costa *et al.*, 2014). Grain rehydration and subsequent ensiling can be used to increase starch digestibility by reducing the protein matrix integrity, providing greater access for microbes and intestinal enzymes to the starch granules (Arcari *et al.*, 2016).

High digestibility of starch is a prerequisite for increasing glucose uptake, either indirectly, through gluconeogenesis -which uses propionate as the main substrate- or directly through glucose uptake in the small intestine (Rowe et al., 1999). Glucose is used in muscle for glycogen synthesis, which plays a key role in the decline of post-mortem muscle pH when converted to lactic acid and hydrogen protons (Volpi-Lagreca and Duckett, 2017). A muscular drop in pH is of great importance for meat quality traits, such as color, water retention capacity and tenderness (Ferguson and Gerrard, 2014). Moreover, glucose is the preferred substrate for the synthesis of intramuscular fat (Smith and Crouse, 1984; Rhoades et al., 2007; Smith et al., 2009).

Although it is well known that rehydration of cereal grains has positive effects on animal performance, to the best of our knowledge no studies have evaluated its effects on meat quality. Thus, our hypothesis was that corn and sorghum rehydration could affect beef quality. Therefore, the aim of this study was to evaluate the effects of two cereals and rehydration on meat quality of Nellore steers in a feedlot.

Materials and methods

Ethical considerations

All animal procedures were approved by the

Animal Care and Use Committee of Universidade Federal de Viçosa (CEUAP), Brazil, protocol number 29/2017.

Animals and treatments

Twenty-four non-castrated Nellore steers with 270 ± 53 kg initial body weight and 7 months of age were used. All animals were identified, weighed and dewormed (Ivermectin 1%, Merial, Paulínia, SP, Brazil; 1 ml per 50 kg body weight) at the beginning of the trial. The treatments were cereal grain type (corn or sorghum) and grain processing method (dry or rehydrated and ensiled), which were offered in the concentrate.

Grain rehydration and ensiling

Corn and sorghum grains were rehydrated sixty days before the beginning of the experiment. A total of 6000 kg of each grain were ground in a hammer mill through a 3-mm screen. Then, samples were collected to determine dry matter content of the ground material. Subsequently, water was added to the ground material until 35% moisture was reached, using a concrete mixer for homogenization. The ground and rehydrated grains were ensiled in horizontal concrete silos at an approximate density of 1000 kg/m³. Silos were covered with plastic canvas, and a 10 cm sand layer was placed on the canvas.

Diets and chemical analysis

The diets were isoproteic and formulated according to the BR-CORTE for 1.2 kg gain per day (Valadares Filho *et al.*, 2010). The diets were composed of 28.44% corn silage and 71.56% concentrate (Table 1). The samples of corn silage and concentrates were analyzed for dry matter (INCT-CAG-003/1 method), ash (INCT-CA M-001/1 method), crude protein (INCT-CA N-001/1 method), ether extract (INCT-CA G-005/1 method), neutral detergent fiber (INCT-CA F-002/1 method) and non-fiber carbohydrates according to Detmann et al. (2012).

	Treatments					
Ingredients (g/kg dry matter)	Cor	n grain	Sorgh	um grain		
	Dry	Rehydrated	Dry	Rehydrated		
Corn silage	284.4	284.4	284.4	284.4		
Dry corn	608.3	-	-	-		
Rehydrated ensiled corn	-	608.3	-	-		
Dry sorghum	-	-	608.3	-		
Rehydrated ensiled sorghum	-	-	-	608.3		
Soybean meal	67.5	67.5	67.5	67.5		
Mineral mix ^a	29.4	29.4	29.4	29.4		
Urea + Ammonium sulfate ^b	10.4	10.4	10.4	10.4		
Composition (g/kg dry matter)						
Dry matter	542.1	467.4	541.7	473.2		
Organic matter	958.8	964.5	961.2	964.1		
Crude protein	133.6	131.0	133.7	130.5		
Ether extract	29.6	36.1	19.4	26.5		
Neutral detergent fiber	238.4	208.4	239.2	219.2		
Non-fiber carbohydrates	557.2	589.0	569.0	588.0		

Table 1. Ingredients and chemical composition of the experimental diets.

^{*a*} Mineral mix: 150 g Ca; 17 g P; 23 g S; 45 g K; 14 g Mg; 57 g Na; 360 mg Cu; 21.6 mg Co; 415 mg Fe; 21 mg I; 715 mg Mn; 6 mg Se; 714 mg monensin sodium.

^b 9:1 urea to ammonium sulfate ratio.

Animal management and slaughter

After 28 days of adaptation, the steers were confined for 140 days in individual covered stalls with concrete floor, water supply and mangers for feeding. The animals were fed twice a day, at 0700 and 1500 h, allowing no more than 10% orts. Silage and concentrate were mixed directly in the manger. Cattle slaughtering was carried out according to animal welfare regulations (MAPA, 2000).

Carcass temperature and pH measurements

After skinning and evisceration, the carcasses were stored in a cold room at 4 °C for 24 h. Temperature and pH were measured in the *Longissimus lumborum* muscle every 2 h using a potentiometer (SevenGoTM, Mettler Toledo-Schwerzenbach, Switzerland).

Collection of meat samples

Meat quality was determined in fresh and aged meat (7 days). After the cooling period, *L. lumborum* muscle samples were collected. Then, two one-inch thick steaks were vacuum-packed, one being immediately frozen (fresh meat) and the other aged for seven days at 4 °C and then frozen at -20 °C (aged meat).

Meat color measurement

Color of subcutaneous fat on *L. lumborum* muscle was determined immediately after carcass cooling. For color analyses, steak samples were thawed at 4 °C for 16 h. Before analysis, steaks were removed from the packages and exposed to oxygen for 30 min. Color readings were obtained with a Hunter MiniScan EZ spectrophotometer (4500L, Hunter Associates Laboratory, Inc., Reston, VA, USA) using illuminant D65, a 31.8

mm port size and a 10° standard observer. The L* (lightness), a* (redness) and b* (yellowness) values were calculated according to the CIELab scale and represented the means of five spectrophotometer readings at specific points on the sample surface.

Thawing, weight loss, and shear force

Thawing loss was calculated as the weight difference of steaks before and after thawing for 16 h at 4 °C. Cooking loss was the weight difference before and after cooking in a water bath at 80 °C for 60 min. Total loss was the weight difference between frozen and cooked steaks (AMSA, 2015).

Shear force measurements were performed on the same steaks used to estimate cooking losses. Five cylindrical samples 1.27 cm in diameter were collected from each steak, parallel to the orientation of the muscle fibers. The samples were sheared perpendicular to muscle fiber orientation using a V-shaped cutting blade at a 60° angle, at 1.016-mm thickness and at a fixed rate of 20 cm/min, coupled with a Warner-Bratzler machine (GR Electrical Manufacturing Company, Manhattan, KS, USA).

Sarcomere length

The sarcomere length was estimated according to the laser diffraction technique (Cross *et al.*, 1981). Six thin filaments were removed from the thawed steak samples parallel to the orientation of the muscle fibers, which were placed separately on a glass slide. One drop of sucrose solution (0.2 M sucrose and 0.1 M NaHPO buffer at pH 7) at 4°C was placed on each filament. Then, the slides were placed in a holder where the laser (632.8 nm) was focused on the filaments using a heliumneon laser (Model 05-LHR-021, MelleGriot, Carlsbad, CA, USA). The diffraction bands were taken at 12 cm below the holder. Six diffraction bands were obtained for each sample and the mean value was used.

Data were analyzed using the Statistic Analysis System, version 9.1 (SAS Institute, Cary, NC, USA, 2003). The following statistical model was used: $Y = \mu + \alpha + \beta + \alpha\beta + \alpha\beta$ e, where $\mu = \text{mean}$, $\alpha = \text{effect of grain type}$, $\beta =$ effect of processing, $\alpha\beta$ = interaction between grain type and processing, and e = randomerror. The experiment was conducted in a 2×2 factorial design and animals were randomly divided into 4 groups, 6 animals in each group. The first factor was cereal grain type in concentrate (corn or sorghum), and the second one was grain processing (dry or rehydrated and ensiled). The Tukey's test was used to compare means between treatments. Statistical differences were considered at p < 0.05.

Results

There was no effect (p>0.05) of grain type, processing or interaction between these factors on the carcass pH during the 24 hours of cooling (Table 2).

Treatments did not affect (p>0.05) meat color parameters (L*, a* and b*) in both fresh or aged steaks (Table 3). However, offered corn grain diets had a higher (p=0.03) intensity of yellow (b*) in subcutaneous fat compared to those containing sorghum grain, regardless of processing type (Table 3).

There were no differences (p>0.05) between treatments for shear force, thawing, cooking and total losses in fresh or aged steaks (Table 4). Sarcomere length was higher (p=0.01) in the aged meat of steers fed sorghum, regardless of the processing method (Table 4).

There were no effects (p>0.05) of cereal grain type, their processing nor interaction between them on the chemical composition of beef (Table 5).

		Treat	tments						
Postmortem times –	Corn grain		Sorghum grain		SEM	p-value			
	Dry	Rehydrated	Dry	Rehydrated	-	G	Р	G×P	
0	7.09	6.98	6.82	6.95	0.11	0.25	0.96	0.36	
2	6.80	6.79	6.66	6.58	0.16	0.17	0.73	0.76	
4	6.60	6.58	6.52	6.40	0.13	0.21	0.53	0.61	
6	6.41	6.47	6.36	6.22	0.15	0.20	0.74	0.39	
8	6.30	6.31	6.34	6.13	0.14	0.53	0.38	0.32	
10	6.30	6.22	6.13	6.02	0.12	0.86	0.33	0.06	
12	6.04	6.15	5.96	5.94	0.13	0.12	0.77	0.53	
14	5.97	6.06	5.95	5.89	0.13	0.33	0.89	0.46	
16	5.94	5.95	5.85	5.83	0.14	0.33	0.85	0.86	
18	5.84	5.93	5.77	5.80	0.13	0.32	0.55	0.78	
20	5.79	5.87	5.75	5.78	0.12	0.53	0.61	0.80	
22	5.78	5.86	5.74	5.68	0.15	0.37	0.96	0.55	
24	5.74	5.81	5.82	5.77	0.16	0.90	0.93	0.60	

Table 2. Average pH of *Longissimus lumborum* muscle evaluated at different postmortem times in carcasses of steers fed corn (dry or rehydrated) or sorghum (dry or rehydrated) grain.

SEM = standard error of the mean.

p-value: G = effect of grain type; P = effect of grain processing; $G \ge P = grain$ type by processing interaction.

Table 3. Average values of lightness (L*), redness (a*) and yellowness (*b) in the fresh or aged steaks and in
the subcutaneous fat of steers fed corn (dry or rehydrated) or sorghum (dry or rehydrated) grain.

Treatments								
Color parameters	Corn grain		Sorghum grain		SEM	p-value		
	Dry	Rehydrated	Dry	Rehydrated	-	G	Р	G×P
				Fresh steak				
L*	41.1	43.0	41.7	41.5	1.13	0.15	0.35	0.45
a*	12.4	13.2	12.8	13.4	0.44	0.80	0.81	0.10
b*	13.3	11.6	12.3	12.7	0.60	0.66	0.28	0.11
			Aged st	eak (7 days postmo	ortem)			
L*	41.7	41.7	43.2	43.3	1.15	0.64	0.08	0.08
a*	12.7	12.1	13.3	12.4	0.81	0.55	0.38	0.89
b*	12.6	13.9	12.7	13.6	0.66	0.87	0.11	0.74
				Subcutaneous fat				
L*	66.6	68.1	70.4	64.9	1.97	0.89	0.32	0.09
a*	10.2	11.2	8.6	10.3	1.06	0.26	0.21	0.75
b*	23.4	23.4	22.5	21.1	0.69	0.03	0.33	0.32

SEM = standard error of the mean.

p-value: G = effect of grain type; P = effect of grain processing; $G \ge P = grain type by processing interaction.$

		Treat	tments						
Aging popied	Corn grain		Sorg	Sorghum grain		p-value			
Aging period -	Dry	Rehydrated	Dry	Rehydrated	-	G	Р	G×P	
				Shear force (kgf)					
0 day	3.2	3.2	3.0	3.3	0.22	0.97	0.58	0.63	
7 days	2.2	2.7	2.7	2.7	0.22	0.31	0.28	0.21	
			Sar	comere length (µm	1)				
0 day	1.9	1.8	1.8	1.8	0.07	0.80	0.79	0.93	
7 days	1.8	1.8	2.1	2.0	0.12	0.01	0.18	0.60	
			Т	hawing losses (%)					
0 day	4.2	4.1	3.7	3.7	1.26	0.72	0.99	0.96	
7 days	5.2	4.1	3.1	4.2	1.06	0.34	0.97	0.31	
			C	ooking losses (%)					
0 day	18.6	19.4	22.5	18.0	2.97	0.69	0.54	0.38	
7 days	21.7	15.4	23.0	18.2	2.99	0.50	0.07	0.80	
				Total losses (%)					
0 day	22.8	23.6	26.2	21.7	3.33	0.82	0.58	0.45	
7 days	21.4	20.4	20.8	19.1	1.16	0.77	0.13	0.60	

Table 4. Average values of shear force, sarcomere length, thawing, cooking and total losses in fresh or aged steaks of steers fed corn (dry or rehydrated) or sorghum (dry or rehydrated) grain.

SEM = standard error of the mean.

p-value: G = effect of grain type; P = effect of grain processing; $G \ge P = grain$ type by processing interaction.

Table 5. Average values of chemical composition of fresh steaks from steers fed corn (dry or rehydrated) or sorghum (dry or rehydrated) grain.

Treatments					n voluo			
Parameters	Corn grain		Sorghum grain		SEM		p-value	
(g/kg)	Dry	Rehydrated	Dry	Rehydrated	-	G	Р	G×P
Moisture	786	796	809	792	1.16	0.41	0.76	0.25
Crude protein	194	199	194	189	1.58	0.75	0.98	0.75
Ash	10	9	9	10	0.07	0.92	0.94	0.07
Fat	42	41	45	36	0.29	0.72	0.13	0.16

SEM = standard error of the mean.

p-value: G = effect of grain type; P = effect of grain processing; G x P = grain type and processing interaction.

Discussion

The final pH values, after 24 hours of cooling, were within the ideal range (5.5 to 5.8) for beef (Ferguson and Gerrard, 2014). Although diets with rehydrated grains provide high energy density, the lack of effect of grain processing on the rate of muscle pH decline could suggest that diets did not influence the synthesis and storage of muscle glycogen. The lack of effect of dietary energy density on pH drop has already been reported in ruminant carcasses (Immonen et al., 2000; Lowe et al., 2002; Apaoblaza et al., 2017). This suggests that although dietary energy density has a strong impact on muscle glycogen synthesis (Pethick and Rowe, 1996; Frylinck et al., 2013), the relationship between muscle glycogen concentration and postmortem pH drop is not always linear since it is also dependent on the activity of enzymes involved in glycogenolysis (Apaoblaza et al., 2015). Similar to our study, the lamb carcass pH also did not differ between animals fed diets containing dry or ensiled high-moisture corn grain (Oliveira et al., 2015).

The lack of treatment effect on meat color parameters could be related to similar values of ultimate pH of carcasses in all experimental diets, which were within the ideal pH range (\leq 5.8) to obtain a normal beef color (Mahmood *et al.*, 2017). Oliveira *et al.* (2015) also did not observe differences in L*, a* and b* parameters in meat of lambs fed dry or ensiled high-moisture corn.

The higher intensity of b^* in the subcutaneous fat of steers fed corn diets could be due to a greater accumulation of carotenoids in these animals (Moloney *et al.*, 2008; Rossi *et al.*, 2016). Carotene and xanthophyll level in corn is 2.0 and 20.1 ppm, while it is 0.3 and 18.0 ppm in sorghum, respectively. These carotenoids are related to yellow pigmentation in products of animal origin (Álvarez *et al.*, 2015). Yellow color in subcutaneous fat is an undesirable characteristic in some southern European markets, which prefer whiter fat

due to an association of yellow fat to low meat quality from older animals (Dunne *et al.*, 2006). Therefore, the use of certain feeds with low capacity for pigmentation of subcutaneous fat, such as sorghum, could be an alternative to meet the demands of these stricter markets.

The tenderness values found in all treatments are within the range considered as tender meat (below 4.6 kgf; Shackelford *et al.*, 1991) and have been reported in other studies under similar production system, genetic group and age (Igarasi *et al.*, 2008; Rubiano *et al.*, 2009).

The values found among all treatments analyzed for sarcomere length are within the natural variation (1.3-2.1 µm) found in tender meat (Starkey et al., 2016). Postmortem sarcomere length interferes with meat tenderness, because a shorter sarcomere results in increased muscle fiber diameter and reduction in the area of action of proteolytic enzymes (Ertbjerg and Puolanne, 2017). Sarcomere length was higher in aged meat for 7 days of steers fed sorghum grain, regardless of the processing method. Proteolysis is the major structural change that occurs during meat aging, and can be related to increases in sarcomere length (Takahashi, 1999). Thus, differences in the activity of proteolytic enzymes such as calpain and cathepsins could be related to differences in sarcomere length between treatments.

The lack of grain type effect on thawing, cooking and total losses have already been reported by Igarasi *et al.* (2008), who evaluated the meat quality of steers fed wet corn or sorghum grains. Kazama *et al.* (2008) also did not observe effect of different types of energy concentrates on thawing and cooking losses in beef. Huck *et al.* (1998) and Gorocica-Buenfil *et al.* (2007) also did not observe differences in meat quality characteristics of cattle fed dry or high-moisture corn grain.

Moisture and protein in meat are relatively constant (approximately 75% moisture and

19 to 25% protein), with little influence of diet (Passini *et al.*, 2002; Lage *et al.*, 2012; Carvalho *et al.*, 2014). The fat content found in the Longissimus muscle is correlated with intramuscular fat deposition, thus, fat content is a reliable marker of marbling (Bindon, 2004). The fat content found in all treatments was above the minimum 3% recommended to obtain the perception of meat flavor (Baghurst, 2004).

Glucose is the main substrate used in growing intramuscular adipocytes (Smith et al., 2009; Hocquete et al., 2010). Rehydration and ensiling of grains increase the digestibility of starch in the total digestive tract (Arcari et al., 2016), indirectly providing more substrate (propionate) through gluconeogenesis or directly (glucose) for the synthesis of intramuscular fat. Thus, the lack of grain processing effect on meat fat content was not expected, and this could be due to the low capacity of intramuscular fat deposition in non-castrated males (Bong et al., 2012; Baik et al., 2014), as well as the absence of genetic predisposition of Nellore steers for deposition of intramuscular fat (Teixeira et al., 2017).

The inability to increase gluconeogenic precursors to promote changes in fat content in the *L. dorsi* muscle of non-castrated Nellore steers has already been shown in studies in which intramuscular fat deposition was not affected by inclusion of crude glycerin (glyconeogenic precursor) in diet (Lage *et al.*, 2014; San Vito *et al.*, 2015).

In conclusion, neither the processing method of the grain nor its interaction with cereal type affected meat quality characteristics of Nellore steers. Cereal grain only affected subcutaneous fat color, which was more yellow in steers fed corn, and sarcomere length of aged beef, which was higher in steers fed sorghum.

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Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

Author contributions

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