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Carcass and meat traits of braford heifers fed diets with triticale silage replacing sorghum silage

Características da carcaça e da carne de novilhas braford alimentadas com silagem de triticale em substituição à silagem de sorgo

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Highlights

Heifer meat from sorghum or triticale silage can be acceptable to consumers.
Triticale and sorghum silages can provide similar carcass traits.
Meat fatty acids do not change in heifers fed triticale and sorghum silage.

Abstract

Different sources of roughage can influence carcass and meat characteristics during beef production. The aim of this study was to evaluate the effects of replacing sorghum silage with increasing levels of triticale silage on carcass traits, meat quality, and fatty acid composition of Braford heifers. Twenty-four Braford heifers were fed feedlots with diets containing either sorghum silage or triticale silage, replacing 30%, 60%, or 100% of the roughage portion with sorghum silage. The animals were slaughtered after 63 days of feeding, and their carcass characteristics, meat composition, and fatty acid profiles were evaluated. Data were analyzed using the F-test at a 5% significance level, and treatment means were compared using Tukey's test. No significant differences ($p > 0.05$) were observed in carcass traits at any level of triticale silage inclusion. Similarly, the chemical composition of the Longissimus lumborum muscle and the fatty acid composition of the meat were not affected ($p > 0.05$). These results suggested that triticale silage can fully replace sorghum silage (up to 100% roughage) in feedlot diets for Braford heifers without negatively affecting carcass traits, meat, or lipid composition.

Key words: Beef cattle. Roughage. Sorghum bicolor. Triticosecale Wittmack. Winter cereals.

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Resumo

Diferentes fontes de volumoso na alimentação de bovinos de corte podem influenciar a produção da carne. Este estudo teve como objetivo avaliar o impacto dos diferentes níveis de substituição da silagem de sorgo por silagem de triticale na carcaça, na carne e na composição de ácidos graxos de novilhas Braford. Vinte e quatro novilhas Braford foram mantidas em confinamento e alimentadas com duas fontes de volumoso: silagem de sorgo e silagem de triticale, esta última substituindo a silagem de sorgo em proporções de 30%, 60% e 100%. Sessenta e três dias após período de alimentação, as novilhas foram abatidas e suas carcaças, carne e composição de ácidos graxos foram analisados. Os dados foram analisados utilizando o teste F com 5% de nível de probabilidade e teste Tukey para a comparação entre as médias. As características de carcaça foram semelhantes entre as novilhas alimentadas com silagem de sorgo e aquelas que receberam diferentes níveis de substituição por silagem de triticale ($p > 0,05$). De forma semelhante, a composição química do músculo Longissimus lumborum não apresentou diferenças significativas entre os grupos ($p > 0,05$). Além disso, a composição dos ácidos graxos da carne não foi influenciada pela substituição da silagem de sorgo pela silagem de triticale na dieta das novilhas ($p > 0,05$). A silagem de sorgo pode ser substituída pela silagem de triticale, incluindo até 100% como fonte de volumoso na dieta de novilhas Braford em sistema de confinamento.

Palavras-chave: Bovinos de corte. Cereal de inverno. Sorghum bicolor. Triticosecale Wittmack. Volumoso.

Introduction

Roughage is the dietary foundation of ruminant feed. Despite the vast production of tropical forage biomass, seasonal deficits in forage availability pose a challenge to beef production. One such alternative is the winter forage. Among them, triticale is the most promising, particularly in regions with limited water resources (Cosentino et al., 2023).

Triticale (x Triticosecale Wittmack) is derived from an interspecific cross between wheat (*Triticum* spp.) and rye (*Secale cereale*). It was initially developed in European countries, including Germany, Scotland, and Hungary (Ayalew et al., 2018). In Brazil, cultivation began in 1985 using a collection of cultivars imported from Canada (Mori et al., 2014).

Triticale cultivation was initially limited due to the poor bread-making quality of the grain (Ayalew et al., 2018). However, their use has expanded primarily through application in animal feed, including whole grains (Purwin et al., 2022), grazing (Ayalew et al., 2018), hay (Ashkvari et al., 2024), and silage (Jung et al., 2022). The use of triticale silage has been evaluated in studies on sheep (Bumbieris et al., 2020), dairy cows (Harper et al., 2017; Ashkvari et al., 2024), and beef cattle (Henz et al., 2020; Cosentino et al., 2023). These studies reported similar animal performances when triticale silage was used instead of other traditional crops, such as wheat, corn, and sorghum (Harper et al., 2017; Henz et al., 2020). However, most of these studies have focused on animal performance, with limited attention given to its potential effects on meat quality.

Different roughage sources can influence carcass traits, meat quality, and lipid composition (Mwangi et al., 2019; Torrecilhas et al., 2023). In animal metabolism, roughage type may affect digestion, pigment deposition, and nutrient absorption, which in turn can alter meat attributes, such as fat content, color, lipid profile, and tenderness (Fruet et al., 2016; Pavan et al., 2023). This is particularly important because these characteristics are closely related to the consumer acceptance of meat (Holman & Hopkins, 2021).

Therefore, the aim of this study was to evaluate the effect of gradually replacing sorghum silage with triticale silage on the carcass traits, chemical composition of meat, and fatty acid profile of feedlot-raised Braford heifers.

Material and Methods

Ethical considerations

The project was approved by the Animal Research Ethics Committee (CEUA) of the State University of Londrina, Paraná, Brazil, and received approval under registration protocol number 2184.2016.97.

Location, animals, and experimental period

The study was conducted in Londrina, Brazil (23°20′10′′ S, 51°09′15′′ W; altitude 610 m). Twenty-four Braford heifers, aged 16 ± 2 months and with an initial body weight of 346.0 ± 11.7 kg, were randomly selected from a commercial herd to form the experimental groups. The heifers were dewormed and vaccinated against foot-and-mouth disease, following the guidelines of the Animal and Plant Health Agency of Paraná [ADAPAR] (2014).

The animals were housed in a covered shed in collective pens, with three animals per pen (total area of 24 m², with 1 m of linear feed per animal), and had free access to water and feed. The study lasted 93 days, comprising a 30-day adaptation and a 63-day data collection period. The heifers were maintained on the experimental diets during the entire adaptation period.

Treatments and experimental design

The Triticales (*Triticosecale* cv. BRS Harmonia) were cultivated in early June 2016 and harvested when the cultivar reached 45% dry matter (DM), yielding an average of 13.330 kg ha^{-1}. Sorghum (*Sorghum bicolor* L. cv. Volumax) was cultivated in October 2016, and sorghum silage was produced in January 2017. Silage was accessed in June 2017 during animal performance evaluation. The chemical composition, fermentation profile, and processing of the silage are described by Oliveira et al. (2021).

The experimental treatments involved gradually replacing sorghum silage with triticale silage in the dry matter of the diet. The replacement levels were 0% (sorghum silage only), 30% (70% sorghum silage and 30% triticale silage), 60% (40% sorghum silage and 60% triticale silage), and 100% (triticale silage only). The experiment was performed using a completely randomized design with six replicates.

The experimental diets consisted of 131 ± 4.9 g kg^{-1} DM crude protein and 2.44 ± 0.04 Mcal kg^{-1} DM of metabolizable energy. The diets were designed to support an average daily gain of approximately 1000 g, based on the guidelines of the Nutrient Requirements of Beef Cattle [NRC] (2016) (Table 1). The concentrate comprised soybean meal and corn supplemented with a vitamin-mineral premix. The roughage-to-concentrate ratio was 40:60. The animals were fed twice daily (08h00 and 17h00) with a total mixed ration (TMR), with allowances of approximately 20% leftovers.

Table 1
Ingredients and calculated chemical composition of diets with different levels of triticale silage to replace sorghum silage

Ingredients (% DM)	Levels of triticale silage (% DM)			
	0	30	60	100
Sorghum silage	40.0	28.0	16.0	_
Triticale silage	_	12.0	24.0	40.0
Corn	41.7	40.4	39.0	37.3
Soybean meal	8.3	9.7	11.0	12.7
Vitamin and mineral mix	10.0	10.0	10.0	10.0
Chemical composition				
Dry matter (g kg^{-1} as feed)	503.1	527.4	554.2	594.4
Crude protein (g kg^{-1} DM)	127.6	126.3	137.1	136.4
Ether extract (g kg^{-1} DM)	31.9	37.0	29.3	29.8
Neutral detergent fiber (g kg^{-1} DM)	293.9	308.2	319.5	342.6
Lignin (g kg^{-1} DM)	10.4	12.5	14.7	17.5
Organic matter (g kg^{-1} DM)	864.3	862.8	862.2	862.1
Total digestible nutrients (g kg^{-1} DM)	672.2	663.1	644.8	624.6
Metabolizable energy (Mcal kg^{-1} DM)	2.53	2.45	2.45	2.36
Fat acid composition (% EE)				
Palmitic acid	12.1	14.2	16.2	19.0
Oleic acid	31.3	26.7	22.3	16.2
Linoleic acid	31.3	33.1	35.1	37.7
Linolenic acid	23.3	20.3	17.2	13.1

DM: dry matter; EE: ether extract. Total digestible nutrients and metabolizable energy calculated according Valadares et al. (2023).

Slaughter, carcass, and meat composition

All the heifers were fasted for 16 h in solid media before slaughter. Animals were weighed before boarding (slaughter body weight [SBW]). The slaughter was conducted in a licensed commercial slaughterhouse under the supervision of the State Sanitary Inspection Service, following the standard practices of the Brazilian beef industry. The animals were stunned using a pneumatic penetration gun, followed by immediate bleeding. Hot carcass weight (HCW) was obtained by recording the carcass weight immediately after slaughter and before the chilling phase. The dressing percentage (DP) was calculated by dividing the HCW value by the SLW value and multiplying it by 100. Carcasses were classified based on conformation (values from 1 = concave to 6 = convex), and subcutaneous fat cover was scored on a scale from 1 (no fat) to 5 (excess fat) based on photographic references adapted from the AMSA guidelines (American Meat Science Association [AMSA], 2001).

A section of the 12^{th}–13^{th} rib was collected for analysis. Subcutaneous fat thickness (FST) was measured using a caliper (AMSA, 2001), and pH was measured using a portable potentiometer with a penetration electrode (0.01 pH units). To measure the *Longissimus lumborum* muscle area (LMA), its contour was traced onto acetate sheets and the area calculated using a planimeter.

The muscle was portioned into pieces of 2.5 cm to assess color, marbling, pressure water loss (PWL), thawing loss (TL), cooking loss (CL), and chemical composition. The color was determined using a Minolta CR 200 colorimeter calibrated to a soft tile pattern, with an evaluation based on the CIELAB system. Marbling was evaluated by comparing the photographic patterns (values of 1-no marbling and 10-abundant marbling) as per AMSA (2001), and pressure water loss (PWL) was assessed according to Hamm (1961).

Muscle samples were weighed while frozen (WF) and kept for 24 hours at 4°C (weight thawing [WT]). After 24 hours, samples were oven-broiled to an internal temperature of 72 to 75°C, then cooled to room temperature and weighed after cooking (WC) (AMSA, 2015). Thawing loss (%TL) was estimated by the difference between the frozen and thawed weights, using the formula: $\%TL = [(FW - TW)/FW] \times 100$, where FW is the frozen weight and TW the thawed weight. Similarly, cooking loss (%CL) was determined using the following equation: $(\%CL) = [(\text{tawed weight (kg, TW)} - \text{cooking weight (kg, CW)}/TW)) \times 100]$.

The chemical composition of the meat was analyzed using raw and finely ground *Longissimus* muscle samples. Moisture content was determined using Method 9341.01 (Association of Official Analytical Chemistry [AOAC], 1990). Additionally, protein, ether extract, and ash contents were analyzed (AOAC, 1990).

Fatty acid composition

The lipid content of the silage samples was evaluated in a commercial laboratory (3RLAB) using Near-Infrared Spectroscopy (NIRS). Lipids from samples of the Longissimus lumborum muscle were extracted using a previously described method Bligh and Dyer (1959), with some modifications as previously described(Andreo et al., 2016).

The fatty acid methyl esters were analyzed using a gas chromatograph equipped with a flame ionization detector (Shimadzu GC-17A). A capillary column (100 m × 0.25 mm) containing 0.25 µm particles in cyanopropyl polysiloxane (CP S 88) was used.

The column temperature program was as follows: 65°C for 15 min; ramped from 65°C to 165°C at a rate of 10°C min^{-1} and held at 165°C for 2 min; ramped from 165°C to 185°C at 4°C min^{-1} and held at 185°C for 8 min; then ramped from 185°C to 235°C at 4°C min^{-1} and held at 235°C for 5 min. Both the injector and detector were set at 260°C, operating under a split ratio of 1:100. The gas flow rates were 1.2 mL min^{-1} for the carrier gas (H_2), 30 mL min^{-1} for the auxiliary gas (N_2), and 30 and 300 mL min^{-1} for the flame gases (H_2 and synthetic air, respectively). The relative retention times of the peaks for fatty acid identification were compared with those of fatty acid methyl ester standards (Sigma). Fatty acid composition data were expressed as a percentage of the normalized peak area.

Statistical analysis

The data were evaluated for normality of the residuals using the Shapiro–Wilk and Bartlett tests before analysis to verify homoscedasticity. For variables that did not show normality, transformations (logarithmic and Box-Cox) were performed. Carcass, meat, and fatty acid composition data were analyzed for variance using a completely randomized design, with four treatments and six replicates per treatment. Statistical significance was determined using the F-test at a 5% probability level, followed by Tukey's test for multiple comparisons at the same significance threshold. All procedures were performed using R software.

Results

Heifers fed diets in which triticale silage was replaced with sorghum silage showed similar carcass characteristics ($p > 0.05$; Table 2). The SBW ranged from 423.5 to 452.1 kg, and the dressing percentage varied between 55.0% and 56.1%. The carcass characteristics measured included fat thickness between 7.1 and 8.8 mm, conformation scores from 3.3 to 3.5 points, Longissimus muscle area ranging from 60.6 to 63.9 cm², and fat classification scores from 2.7 to 3.3 points.

Similarly, the replacement of sorghum silage with triticale silage did not affect ($p > 0.05$) the chemical composition or physical traits of the Longissimus lumborum muscle (Tables 3 and 4). The muscle's chemical composition was as follows: crude protein ranging from 22.6% to 23.1% NM, ether extract from 2.8% to 3.8% NM, and ash content at approximately 1.1% NM. Meat traits included pH values between 5.4 and 5.5, color coordinates L from 36.5 to 37.5, a from 14.7 to 16.3, and b* from 11.0 to 14.7. The marbling scores ranged from 1.8 to 3.0. Tenderness-related traits included water loss due to pressure ranging from 22.2% to 26.3%, thawing loss from 3.4% to 3.8%, and cooking loss from 27.7% to 35.9%.

Table 2
Carcass characteristics of Braford heifers fed diets containing different levels of triticale silage to replace silage sorghum

Ingredients (% DM)	Levels of triticale silage (% DM)				SEM	*p-value*
	0	30	60	100		
Slaughter body weight (kg)	452.1	437.1	431.5	423.1	0.85	0.926
Dressing percentage (%)	55.1	56.1	54.9	56.3	0.36	0.419
Conformation	3.5	3.2	3.3	3.3	0.27	0.863
Fat classification	3.3	2.7	3.0	3.0	0.26	0.402
Logissimus muscle area (cm^2)	60.6	60.8	63.9	62.6	1.88	0.926
Fat thickness (mm)	8.8	8.9	7.7	7.1	0.09	0.411

DM: dry matter; SEM = standard error of mean. Conformation based on the AMSA (2001) classification system where E = 1 and P=5. Fat classification based on a 5-point scale where 1 - cover fat absent to 5 - excess cover fat.

Table 3
Chemical composition of the *Longissimus lumborum* of Braford heifers fed diets containing different levels of triticale silage to replace silage sorghum

Ingredients (% DM)	Levels of triticale silage (% DM)				SEM	*p-value*
	0	30	60	100		
Water (%)	73.1	71.9	72.6	73.0	0.2	0.304
Protein (% NM)	22.9	23.2	22.6	23.1	0.1	0.606
Ether extract (% NM)	2.9	3.8	3.7	2.8	0.2	0.200
Ash (% NM)	1.1	1.1	1.1	1.1	0.0	0.845

NM: natural matter; DM: dry matter; SEM: standard error of mean.

Table 4
Characteristics of *Longissimus lumborum* of Braford heifers fed diets containing different levels of triticale silage to replace silage sorghum

Variable		Levels of triticale silage (% DM)				SEM	*p-value*
		0	30	60	100		
Water loss by pressure (%)		22.3	22.6	26.4	24.3	0.8	0.114
Thawing loss (%)		3.7	3.4	3.5	3.9	0.2	0.902
Cooking loss (%)		31.8	35.9	32.9	27.8	1.6	0.351
pH		5.4	5.6	5.5	5.5	0.2	0.610
	L*	37.1	36.6	37.6	36.6	0.3	0.598
Color	a*	15.6	15.7	16.3	14.8	0.4	0.617
	b*	11.5	11.4	14.8	11.0	0.2	0.371
Marbling		2.5	3.0	2.3	1.8	0.5	0.411

DM: dry matter; SEM: standard error of mean.

The fatty acid composition of the Longissimus lumborum muscle was also not affected ($p > 0.05$) by the dietary replacement of sorghum silage with triticale silage at any inclusion level (Table 5).

Table 5
Fatty acid composition of Braford heifers fed diets containing different levels of triticale silage to replace silage sorghum

Variable	Triticale silage levels (% DM)				SEM	*p-value*
	0	30	60	100		
Total SFA	**45.1**	**43.5**	**44.4**	**44.8**	0.64	0.832
14:0	2.73	2.30	2.57	2.90	0.11	0.262
15:0	0.42	0.26	0.49	0.51	0.05	0.380
16:0	27.2	25.5	26.2	27.4	0.37	0.242
18:0	14.8	15.3	15.1	13.9	0.53	0.789
20:0	0.00	0.02	0.03	0.00	0.00	0.283
Total MUFA	**50.1**	**51.2**	**50.6**	**50.6**	0.63	0.952
14:1	0.02	0.03	0.08	0.04	0.01	0.114
16:1-7	3.46	3.39	3.46	4.05	0.19	0.601
16:1-9	0.94	0.96	1.23	0.92	0.06	0.304
18:1-9	45.2	46.5	45.3	45.5	0.59	0.882
20:1	0.36	0.36	0.43	0.12	0.04	0.099
Total PUFA	**4.76**	**5.32**	**5.01**	**4.58**	0.35	0.899
ω3	**0.89**	**0.76**	**0.94**	**0.87**	0.04	0.491
18:3-3	0.19	0.29	0.32	0.31	0.02	0.288
20:5-3	0.22	0.23	0.22	0.26	0.03	0.979
22:5-3	0.49	0.45	0.30	0.43	0.04	0.599
ω6	**3.84**	**4.34**	**4.16**	**3.57**	0.29	0.812
18:2-6	2.69	2.98	2.97	2.45	0.18	0.728
20:3-6	0.18	0.21	0.19	0.16	0.02	0.855
20:4-6	0.94	1.03	0.88	0.86	0.09	0.925
22:4-6	0.02	0.00	0.03	0.05	0.01	0.226
22:5-6	0.00	0.00	0.05	0.04	0.11	0.375
ω6/ ω3	**4.49**	**4.53**	**5.08**	**3.72**	0.27	0.407
PUFA/SFA	**0.12**	**0.11**	**0.10**	**0.10**	0.04	0.237

DM: dry matter; SEM: standard error of mean. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

Discussion

Alternative forages in cattle feedlots are essential for sustainable production. Winter cereals in animal feed can promote performance comparable to that of other crops, such as sorghum. The results of the current study indicated that heifers fed triticale silage had similar SBW, dressing percentage, and carcass composition to those fed sorghum silage. The similar composition between the carcasses of heifers fed triticale silage and those fed sorghum silage suggested that both silages provide comparable energy and protein levels despite the physiological differences between the plants. The fat classification predominated in the medium category (3), and fat thickness was satisfactory for preventing cold loss (Heggli et al., 2023). The carcass conformation was straight (3), and the LMA demonstrated low muscularity in the carcasses (Pavan et al., 2023).

Although there is no official payment program for carcass quality in the Brazilian market, many companies pay farmers based on carcass quality, such as conformation. Therefore, the use of sorghum and triticale silage to produce high-quality carcasses is a valuable strategy. In addition, the cultivation of triticale allows the use of permanent growth areas that remain idle during winter and can be used for growing crops for silage production, enabling the rational use of soils and providing high-quality nutritional forage for the expansion of livestock (Horst et al., 2018; Henz et al., 2020).

Despite variations in silage proportions, the different diets had a mean metabolizable energy content of 2.44 ± 0.04 Mcal kg^{-1} DM and 131.8 g kg^{-1} DM of crude protein, resulting in a similar chemical composition of the meat. The chemical composition of meat can be influenced by several animal-related factors, such as genetics, age, and sex, as well as environmental factors, particularly diet. However, in the present study, the replacement of sorghum silage with triticale silage at different inclusion levels did not alter the chemical composition of meat. Freitas et al. (2014) reported similar values in the *Longissimus dorsi* muscle of Braford heifers finished in feedlots and fed corn-silage-based diets.

The results of meat pH at 24 hours were within the normal range (pH 5.5 to 5.8) for beef. The final pH of the meat (mean 5.48) likely prevents water loss (Boakye & Mittal, 1993), and similar conditions before slaughter favor a consistent decrease and stabilization of the final meat pH. Regarding meat color, heifer meat presented normal L* values (a reference to meat cattle 33.2 to 41.0) and lower b* values, which are indicative of younger cattle (Boakye & Mittal, 1996). The characteristics of the meat of heifers fed sorghum and triticale silage presented in this study indicate that they would be acceptable to consumers, according to Holman and Hopkins (2021).

The silages had different fatty acid compositions (Table 1); however, this variation was insufficient to alter the fatty acid profile of meat (Table 5). Harper et al. (2017) observed that replacing corn silage with triticale silage reduced the total concentration of trans-fatty acids in milk. Changes in the lipid composition of meat are often observed when different feeding strategies are applied (Torrecilhas et al., 2023). The type of roughage, such as silage, can influence the fatty acid composition. However, after harvest, lipases and lipoxygenases promote the oxidation of free fatty acids in silage, leading to a reduction in linoleic and linolenic acid concentrations (Bueno et al., 2020). Some studies have reported significant alterations in fatty acid profiles when high-moisture triticale grains were used in animal diets (Purwin et al., 2022).

To our knowledge, this is the first report on the effects of triticale silage on the fatty acid composition of heifer meat. Understanding the fatty acid profile of foods is essential for human health, and recent studies have increasingly focused on this topic (Smith et al., 2020; Badawy et al., 2023). In this study, the polyunsaturated fatty acid (PUFA)/ saturated fatty acid (SFA) ratio in meat ranged from 0.10 to 0.12 across treatments ($p > 0.05$), which is below the recommended value of 0.4 for red meat in the human diet (Department of Health, 1994), indicating a predominance of saturated fatty acids. The ω6/ω3 ratio did not differ significantly among treatments and was consistent with previously reported values (Castagnino et al., 2018). Dietary guidelines recommend an n−6/ n−3 fatty acid ratio of 1:1 to 4:1 for optimal health outcomes (Simopoulos, 2002).

Conclusion

Triticale and sorghum silages promoted similar carcass, meat, and fatty acid compositions. Therefore, triticale silage can serve as an alternative feed for beef cattle feedlots during seasonal periods of forage deficit.

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