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ANIMAL REPRODUCTION

Physicochemical characterization and lipid profile of meat from crossbred steers receiving different supplementation

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ABSTRACT: *The aim of this study was to evaluate the carcass characteristics and the physicochemical parameters, centesimal composition, and fatty acid profile of the longissimus lumborum muscle of crossbred steers on a Brachiaria (Syn. Uruchloa) brizantha cv. Marandu pasture during the growing and finishing phases. Twenty-two uncastrated steers ½ Holstein/Zebu, with an average initial weight of 210 kg ± 8.2 kg and eight months of age, were distributed in a completely randomized design, in which the experimental period was fractionated in to three seasons associated with two nutritional plans (NP1 and NP2) and 11 animals by treatment: NP1– mineral mixture ad libitum in rainy seasons + nitrogen/energy supplement at 1 g.kg^{-1} body weight (BW) in the dry season; and NP2 – nitrogen/energy supplement at 2 g.kg^{-1} BW in rainy season 1 and in the dry season + nitrogen/energy supplement at 1 g.kg^{-1} BW in rainy season 2, provided daily at 1000 h. Of the carcass measurements, differences were only observed (p>0.05) between the nutritional plans for loin-eye area corrected for 100 kg of hot carcass weight. Among the physicochemical parameters, only shear force was influenced (p>0.05) by the treatments, with higher values obtained in Nutritional Plan 1. The centesimal composition and fatty acid profile were not influenced (P<0.05) by supplementation. Nutritional plans used in the growing and finishing phases involving low levels of protein-energy supplementation do not lead to changes significant in carcass characteristics and meat. Nutritional Plan 1 is the most appropriate because it presents a lower cost.*
Key words: *loin-eye area, mineral mixture, nutritional plan, saturated fatty acids.*

Caracterização físico-química e perfil lipídico da carne de novilhos mestiços recebendo diferentes suplementações

RESUMO: *Objetivou-se avaliar as características da carcaça, parâmetros físico-químicos, composição centesimal e perfil de ácidos graxos do músculo Longissimus lomborum de novilhos mestiços em pastagem de Brachiaria (Syn. Uruchloa) brizantha cv. Marandu, durante as fases de recria e terminação. Foram utilizados 22 novilhos (½ Holandês e ½ Zebu) não castrados, com peso inicial médio 210 kg ± 8,2 kg e oito meses de idade, distribuídos em delineamento inteiramente casualisado, com período experimental dividido em três estações, associada com 2 planos nutricionais (PN1 e PN2) e 11 animais por tratamento: PN1 (mistura mineral ad libitum nas estações chuvosas (EC) e suplemento nitrogenado/energético na quantidade de 1 g.kg^{-1} do peso corporal (PC) na estação seca) e PN2 (suplemento nitrogenado/energético de 2 g.kg^{-1} PC nas EC 1 e na seca, e suplemento nitrogenado/energético na quantidade de 1 g.kg^{-1} PC na EC 2) fornecidos diariamente às 10:00h. Para as características de carcaça foi observado diferença (p>0,05) entre os planos nutricionais, apenas para área de olho de lombo corrigida para 100 kg de peso de carcaça quente. Para os parâmetros físico-químicos apenas a força de cisalhamento foi influenciada pelos tratamentos (P>0,05) e foi maior para o plano nutricional 1. A composição centesimal e o perfil de ácidos graxos, não foram influenciados (p<0,05) pela suplementação. Planos nutricionais de recria e terminação com baixos níveis de suplementação proteico-energética não promove alterações significativas nas características da carcaça e da carne. O plano nutricional 1 é o mais indicado porque apresenta menor custo.*
Palavras-chave: *área de olho de lombo, mistura mineral, plano nutricional, ácidos graxos saturados.*

INTRODUCTION

Nutritional management involving use of supplementation generates changes in the main characteristics of carcass and meat in comparison to pasture-only diets. It is; therefore, an interesting technique for advancing the time for slaughter and improving carcass and meat traits, since it elevates the energy uptake of the animal and its rate of weight gain, which may result in the increased deposition of muscle tissue (BARONI et al., 2010; MACHADO et al., 2012). Furthermore, inclusion of nutritional plans in the diet of grazing cattle positively affects the quality of their meat (MENEZES et al., 2014),

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interfering with its tenderness, color, intramuscular fat content, and fatty acid profile.

Bovine meat has significant amounts of conjugated linoleic acid, which is considered to be anti-carcinogenic and anti-atherosclerotic, among having other benefits. Moreover, it has been demonstrated that an increase in the concentrations of unsaturated fatty acids; e.g., polyunsaturated fatty acids of the omega-3 and omega-6 series, is beneficial for human health. This is a consequence of the high concentrations of omega-3 fatty acids (C18:3) present in forages, whereas high-concentrate diets have higher levels of linoleic acid (C18:2), a precursor of the omega-6 series (PONNAMPALAM et al., 2014).

In this scenario, the present study proposes to evaluate the carcass characteristics and physicochemical parameters, centesimal composition, and fatty acid profile of the *longissimus lumborum* muscle of crossbred steers kept on a *Brachiaria* (Syn. *Uruchloa*) *brizantha* cv. Marandu pasture receiving two nutritional plans during growing and finishing phases.

MATERIAL AND METHODS

The trial was carried out on Princesa do Mateiro Farm, located in Ribeirão do Largo - BA, Brazil, over 378 days of data collection after a 14-day adaptation period. Twenty-two uncastrated steers ½ Holstein/Zebu, with an average initial weight of 210 ± 8.2 kg and eight months of age, were used in a 7-ha experimental area composed of fourteen 0.5-ha paddocks of *Brachiaria* (Syn. *Uruchloa*) *brizantha* cv. Marandu with two central corridors equipped with water and feed troughs. Rotational-grazing method was adopted, with five grazing days and 30 rest days per paddock. Animals were distributed in a completely randomized design, in which the experimental period was fractionated into three seasons associated with two nutritional plans (NP1 and NP2) and 11 replications by treatment and by picket:

Rainy season 1 - Between February 15 and May 7, 2014, where NP1: mineral mixture *ad libitum* and NP2: nitrogen/energy supplement of 2 $g.kg^{-1}$ body weight (BW).

Dry season - Between June 7 and November 22, 2014, where NP1: nitrogen/energy supplement of 1 $g.kg^{-1}$ BW and NP2: nitrogen/energy supplement of 2 $g.kg^{-1}$ BW.

Rainy season 2 - Between November 23, 2014 and March 9, 2015, NP1: mineral mixture ad libitum and NP2: nitrogen/energy supplement of 1 $g.kg^{-1}$ BW.

The growing phase started in the rainy season 1 and when they reached an average BW of 340 kg ± 8.2 kg, the animals entered the finishing phase in the dry season of the year, ending in the rainy season 2 with an average BW of 465 ± 8.6 kg.

Nitrogen/energy supplement was provided daily at 1000 h. The concentrate supplement was formulated according to the NRC (2000), so as to provide a daily gain of 700 g per animal (Table 1) at all stages. Chemical-bromatological composition of *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu and supplement can be seen in table 2.

At the end of the experiment, animals were weighed and taken to the commercial slaughterhouse in Itapetinga, southwest Bahia State, Brazil. Steers were slaughtered after a 24-h rest period under solid- and liquid-feed deprivation, following the norms established by normative instruction no. 3 of January 17, 2000, of the Ministry of Agriculture, Livestock and Supply, and in accordance with the normal slaughter flow of the abattoir.

After slaughter, carcasses were identified and weighed to determine the hot carcass yield. The hot carcass weight (HCW) was determined immediately after slaughter, before the carcass was moved to a cold

Table 1 - Composition ($g.kg^{-1}$) of the supplements on a fresh-matter basis.

Ingredient	---Supplement---	
	Nitrogen/energy	Mineral mixture[1]
Ground corn	454.40	-
Soybean meal	449.35	-
Urea	49.93	-
Mineral mixture	46.32	1000

[1]Guaranteed levels: calcium, 175 g; phosphorus, 60 g; sodium, 107 g; sulfur, 12 g; magnesium, 5000 mg; cobalt, 107 mg; copper, 1300 mg; iodine, 70 mg; manganese, 1000 mg; selenium, 18 mg; zinc, 4000 mg; iron, 1400 mg; fluorine (maximum), 600 mg.

Table 2 - Chemical-bromatological composition of *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu and supplement.

Item	----------------------*Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu-----------------------			Supplement
	Rainy season 1	Dry season	Rainy season 2	
DM[1]	314.5	348.7	300.2	914.9
CP[2]	72.4	71.8	92.0	437.7
EE[2]	20.8	22.2	28.2	31.7
CNFcp[2]	172.3	200.7	199.8	485.1
NDFcp[2]	635	589.5	606.2	39.9
ADF[2]	315.2	303.1	289.8	42.0
Lignin	23.1	28.4	20.0	8.0
Ash [2]	99.5	109.5	73.8	96.9
TDN[3]	512.7	489.6	635.6	670.6

[1]g/kg of naturam matter. [2]g/kg dry matter; TDN[3]: Estimated.

chamber. The hot carcass yield (HCY) was determined as the ratio between the HCW and final body weight. A horizontal section was made between the 12th and 13th ribs in the left half-carcass to expose the *longissimus lumborum* and measure the muscle area, which was obtained by outlining it onto tracing paper. The area was then measured using a planimeter to determine the loin-eye area (LEA), in cm^2. The "plastic plate" used was developed by LUCHIARI FILHO (2000). The backfat thickness (BFT) was measured in the same location, and determined as the arithmetic mean of three observations in the cranial, medial, and final parts of the muscle (LUCHIARI FILHO, 2000). The following equation was used to obtain the LEA per 100 kg live weight (cm^2):

LEAHCW = (LEA) / (HCW/100)

Loin-eye area ratio was determined as the LEA height divided by its width, which were measured using a graduated ruler. The muscles were packed, labeled, separated individually, and immediately stored at a temperature of –10 °C until laboratory analyses.

According to the gravimetric method of AOAC (2010), with calcination at 550 °C for 6 h in a muffle furnace, the mineral matter was determined. About 2 g of meat samples were placed in crucibles, taken to the muffle oven for their burning, and then placed in the desiccator until they reached a constant weight, followed by a new weighing. Crude protein was analyzed using the micro-Kjeldahl method of AOAC (2010), which is based on the quantification of total nitrogen and, by the conversion factor of 6.25, the crude protein value is determined, and total lipids were analyzed following the method proposed by BLIGH & DYER (1959).

To quantify the fatty acids, samples of meat, concentrate supplement (corn and soybean meal), and forage were subjected to lipid extraction, following the methodology proposed by BLIGH & DYER (1959).

Triacylglycerols were trans-esterified according to International Organization for Standardization (ISO) method 5509 (1978). Fatty acid methyl esters were identified by comparing the retention times of the sample components with a mixture of 37 standards of fatty acid methyl esters (189-19 Sigma, USA) and by comparing with the retention times of methyl esters of standards containing the geometric isomers c9t11 and t10c12 of linoleic acid (O-5632 Sigma, USA).

The cholesterol content was determined in duplicate by direct saponification and subsequent extraction with hexane, following SALDANHA et al. (2004), with modifications in the time and type of saponification, based on SALDANHA et al. (2006). A high-performance liquid chromatograph (was used with an analysis time of 20 min per sample. Cholesterol was identified by comparing the retention time of the samples with the standards and quantified by external standardization.

Color was determined by colorimetry, using a spectrophotometer (Miniscan EZ-4500, Hunterlab). Color values were expressed using the CIE (International Commission on Illumination) $L^*a^*b^*$ system, which has a uniform scale, where L^* stands for lightness, which ranges from 0 (pure black) to 100 (pure white); a^* stands for hue, which represents the variation from red to green; and b^* stands for saturation, which represents the variation from yellow to blue. The L^*, a^*, and b^* coordinates were measured at two distinct points of the muscle internal surface, and the average of the duplicates of each coordinate was later calculated per animal. The myoglobin content was estimated as the ratio between a^* and b^*.

The water-holding capacity (WHC) was determined by difference in weight after in weight the meat sample was dried in an oven. Cooking loss (CL) followed by the methodology described by JOHNSON et al. (1989) was determined by as the difference between the initial and final weights of each sample. Shear force was determined using a Texture Analyser device coupled to a Warner-Bratzler stainless steel blade, with 50-kg capacity, adopting the procedure standardized and proposed by WHEELER et al. (1993). The pH was determined in triplicate at three different points of the muscle using a Quimis 0400MT benchtop pH meter with a buffer solution (pH 4 to 7).

The studied variables were statistically analyzed by analysis of variance and F test at the 0.05 probability level, using the procedures described in the SAS computer package (Studio version), according to the following model:

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

where:

Yij = experimental response;

μ = general constant;

ti = fixed effect of treatment;

eij = random error associated with each observation.

RESULTS AND DISCUSSION

The HCW, carcass dressing percentage (DP), LEA, BFT, and LEA ratio were not influenced (p>0.05) by nutritional plans (Table 3). Average carcass weight (223.29 kg) was near the standard values required by the meatpacking industry (a minimum of 225 kg), which seeks young animals with heavier carcasses to obtain a lower cost per kilogram of meat processed in abattoirs. The average DP obtained in the present experiment was 47.70%, which is within the range of 45% to 50% described in the literature for crossbred animals (VAZ et al., 2014)

According to LIMA et al. (2015), the DP of cattle is influenced by extrinsic factors (breed, sex, body condition, and slaughter weight) and intrinsic factors (feeding and finishing system). However, the amount of supplement used was not sufficient to change DP.

Loin-eye area corrected for 100 kg.carcass^{-1} (LEA_{HCW}) was higher (p<0.05) in the animals on Nutritional Plan 1. This difference may be related to the higher HCW observed in the steers receiving Nutritional Plan 2.

TOLDRÁ (2010) reported that LEA is related to the amount of muscle in the carcass, whereas the BFT is directly linked to the total fat in the carcass and inversely related to the total amount of muscle. Backfat is one of the most important carcass traits in the evaluation of meat quality, and it is influenced by the animal nutrition. However, no effect of supplements was detected on this variable, whose values were within the range deemed ideal (minimum 3 mm and maximum 6 mm) (LUCHIARI FILHO, 2000).

Shear force was the only physicochemical parameter influenced by the nutritional plans (P<0.05), and the animals receiving Nutritional Plan 1 provided meat with a higher shear force value (Table 4).

Table 3 - Evaluation of the carcass of crossbred steers supplemented while on a *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu pasture.

Item	------------------------Nutritional plan[1]	------------------------	CV%	Significance[2]
	1	2		*p*
HCW, kg	214.36	232.22	14.79	0.2302
DP, %	47.56	47.85	2.77	0.6147
BFT, mm	3.26	3.03	26.12	0.5128
LEA, cm^2	49.18	44.70	11.57	0.0751
LEA_{HCW}	23.28	19.36	14.92	0.0112
LEA ratio, cm	0.75	0.67	15.85	0.1073

[1]Nutritional Plan 1: mineral mixture *ad libitum* (rainy seasons 1 and 2) + nitrogen/energy supplement at 1 g.kg^{-1} body weight (BW) (dry season); Nutritional Plan 2: nitrogen/energy supplement at 2 g.kg^{-1} BW (rainy season 1) + nitrogen/energy supplement at 2 g.kg^{-1} BW (dry season) + nitrogen/energy supplement at 1 g.kg^{-1} BW (rainy season 2); [2](p) significant if p<0.05, not significant if p>0.05, at the 5% probability level by the F test. HCW = hot carcass weight; DP = carcass dressing percentage; BFT = backfat thickness; LEA = loin-eye area; LEA_{HCW} = loin-eye area corrected for 100 kg/carcass; LEA ratio = ratio between sirloin height and width.

Table 4 - Physicochemical parameters of the *longissimus lumborum* muscle of crossbred steers supplemented while on a *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu pasture.

Physicochemical parameter	-----------Nutritional plan[1]------------		CV%	Significance[2]
	1	2		*p*
SF, kgf	6.22	4.66	16.90	0.0011
WHC, %	73.07	71.54	9.96	0.6328
CL	38.89	42.50	15.85	0.2143
pH	5.91	5.73	4.45	0.1343
L^*	36.48	34.16	14.17	0.3020
a^* color	12.26	11.70	15.42	0.4970
b^* color	13.57	14.61	14.26	0.2496
Myoglobin	0.92	0.80	16.75	0.0867

[1]Nutritional Plan 1: mineral mixture *ad libitum* (rainy seasons 1 and 2) + nitrogen/energy supplement at 1 $g.kg^{-1}$ body weight (BW) (dry season); Nutritional Plan 2: nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (rainy season 1) + nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (dry season) + nitrogen/energy supplement at 1 $g.kg^{-1}$ BW (rainy season 2); [2](p) significant if $p<0.05$, not significant if $p>0.05$, at the 5% probability level by the F test. SF = shear force; WHC = water-holding capacity; CL = cooking loss; pH = potential of hydrogen; L^* = reflectance or lightness percentage; a^* = variation in color from red to green; b^* = variation in color from yellow to blue.

The SF observed in the meat of animals receiving Nutritional Plan 1 was 6.22 kgf. According to LAWRIE (2004) and RUBIANO et al. (2009), the limit that separates soft from tough meat is between 4.5 and 6.0 $kgf.cm^{-2}$. Despite being influenced by genetic group, the SF can also be affected by nutrition. Presence of muscle fibers and fat content in the muscle might also have contributed to the increased shear force reported in the meat from animals that received less supplementation during the experiment, possibly because they had to move around more in the pasture and consequently eat more forage to meet their nutritional demands.

Water-holding capacity values were in line with those described in the literature for beef, which range from 70% to 75%. This is a very important parameter in the determination of the meat quality, since it is related to color, texture, consistency, juiciness, and tenderness of cooked meat. There were no variations in total fluid loss between the treatments, which most likely was because there were no differences in the meat pH and intramuscular fat content, measured from total lipids. The final pH of the meat from Nutritional Plans 1 and 2 was near the 5.4 to 5.8 considered normal for beef cattle in the meat industry (ZHANG et al., 2005). There was no difference between nutritional plans, since the slaughter of animals was carried out in the refrigerator, presenting the same pre-slaughter management conditions.

The moisture, mineral matter, crude protein, total lipids, and cholesterol values (Table 5) in

Table 5 - Centesimal composition of the *longissimus lumborum* muscle of crossbred steers supplemented while on a *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu pasture.

Centesimal composition	-----------Nutritional plan[1]-----------		CV%	Significance[2]
	1	2		*p*
Moisture, %	74.90	74.60	1.51	0.5494
Mineral matter, %	1.13	1.12	3.43	0.5609
Crude protein, %	19.20	19.32	4.08	0.7333
Total lipids, %	2.66	2.28	29.94	0.2621
Cholesterol, mg/100 g	38.32	39.09	13.88	0.7436

[1]Nutritional Plan 1: mineral mixture *ad libitum* (rainy seasons 1 and 2) + nitrogen/energy supplement at 1 $g.kg^{-1}$ body weight (BW) (dry season); Nutritional Plan 2: nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (rainy season 1) + nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (dry season) + nitrogen/energy supplement at 1 $g.kg^{-1}$ BW (rainy season 2); [2](p) significant if $p<0.05$, not significant if $p>0.05$, at the 5% probability level by the F test.

the *longissimus lumborum* muscle were not influenced (p>0.05) by the nutritional plans.

Color parameters (L^*, a^*, and b^*) were also not influenced by the nutritional plans. Lightness (L^*) was influenced by the water-holding capacity and ranged from 34.16 to 36.48. Red intensity (a^*) values varied between 11.70 and 12.26, which was considered low and related to the presence of pigments such as myoglobin. The b^* values for Nutritional Plans 1 and 2 were 13.57 and 14.61, respectively, characterizing a high yellow index. This greater yellow intensity is associated with the composition of carotenoids derived from the pasture.

LIMA et al. (2015) evaluated the centesimal composition of cattle carcasses and reported an average moisture content of 73.58% in the *longissimus* muscle. Similar results were observed by COSTA et al. (2013) and ANDRADE et al. (2014), who reported respective average moisture contents of 75.14% and 76.10%. Those authors also did not find significant differences between treatments for crude protein contents in the meat and ash.

There was no difference (p>0.05) between the nutritional plans tested (Table 6) for fatty acid profile. The lack of effects of the nutritional plans on the fatty acid profile is likely explained by the fact that the higher amount of supplement (0.2% BW/day) provided to the animals in Nutritional Plan 2, as compared with the group that received only mineral supplementation during the majority of the experimental period, was not sufficient to bring about alterations in the fatty-acid transformation processes occurring in the rumen.

The diet supplied to animals contained a larger proportion of linoleic, palmitic, oleic, and linoleic acids. However, when the unsaturated

Table 6 - Fatty acid profile in the *Longissimus lumborum* muscle of crossbred steers supplemented while on *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu pasture.

Fatty acid	-----------Nutritional plan[1]----------		CV%	Significance[2]
	1	2		*p*
C14:0 (myristic)	2.44	2.47	25.03	0.9156
C14:1 (myristoleic)	0.35	0.25	51.00	0.1647
C15:0 (pentadecanoic)	0.65	0.67	17.64	0.6903
C15:1 (10-pentadecanoic)	0.35	0.35	11.79	0.8276
C16:0 (palmitic)	25.54	25.25	9.68	0.8042
C16:1 (palmitoleic)	1.70	1.58	22.83	0.4748
C17:0 (margaric)	0.54	0.64	28.74	0.2323
C17:1 (heptadecenoic)	0.67	0.67	19.58	0.9170
C18:0 (stearic)	24.72	26.06	14.37	0.4469
C18:1n-9t (elaidic)	3.28	3.26	20.31	0.9453
C18:1n-9c (oleic)	32.18	31.60	12.92	0.7726
C18:2n-6 (linoleic)	3.64	3.35	42.26	0.6842
C18:3n-6 (γ-linolenic)	0.20	0.23	23.11	0.2834
C18:3n-3 (α-linolenic)	0.89	0.82	36.36	0.6481
C18:2 c9 t11 CLA	0.12	0.11	18.88	0.7071
C18:2 t10 c12 CLA	0.08	0.07	11.44	0.1300
C20:0 (arachidic)	0.37	0.35	25.68	0.5608
C20:2 (eicosadienoic)	0.56	0.52	18.46	0.4586
C20:3n-3 (eicosatrienoic)	0.13	0.10	49.93	0.2035
C20:3n-6 (dihomo-γ-linoleic)	0.16	0.23	57.00	0.3689
C20:4n-6 (arachidonic)	0.83	0.78	73.12	0.8562
C22:1n-9 (erucic)	0.13	0.14	87.77	0.8071
C22:2 (docosadienoic)	0.14	0.07	154.95	0.4054
Unidentified	0.33	0.43	71.64	0.5002

[1]Nutritional Plan 1: mineral mixture *ad libitum* (rainy seasons 1 and 2) + nitrogen/energy supplement at 1 $g.kg^{-1}$ body weight (BW) (dry season); Nutritional Plan 2: nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (rainy season 1) + nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (dry season) + nitrogen/energy supplement at 1 $g.kg^{-1}$ BW (rainy season 2); [2](p) significant if p<0.05, not significant if p>0.05, at the 5% probability level by the F test.

linoleic and linolenic acids are ingested by the ruminant, rumen microorganisms hydrolyze them and convert them to saturated forms in a process called hydrogenation. In this way, the lipids present in the tissues of ruminants are more saturated and the relatively low percentage of unsaturated fatty acids in the fat of ruminants is known for being associated with their rumen metabolism, biosynthesis of endogenous fatty acids, and triacylglycerol (OR-RASHID et al., 2011). This explains the greater proportion of saturated fatty acids (SFA) in the diet. These acids are known for their hypercholesterolemic nature, with myristic (C14:0) and palmitic (C16:0) being the most undesirable. Stearic acid (C18:0), which composes approximately one-third of the SFA content, was the fatty acid most present in the total fatty acid profile in the present study. It has beneficial properties (LIMA et al. 2017), as it is transformed into oleic acid (C18:1) so quickly that it does not have a cholesterol-raising effect. The values reported in this study resulted in a higher proportion of SFA, which averaged 54.85%, followed by 38.25% MUFA and 6.5% PUFA.

There was no effect of the nutritional plan ($p>0.05$) on the proportions of saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), omega-6 (n-6), or omega-3 (n-3) fatty acids, or PUFA:SFA and n-6:n-3 ratios (Table 7).

According to PINHO et al. (2011), in animals finished on pasture, the lipid fraction is characterized for having larger quantities of polyunsaturated fatty acids. BRESSAN et al. (2016) observed 47.29% SFA, 41.10% MUFA, and 10.82% PUFA when the animals were finished on pasture and 49.63%, 41.30%, and 9.07% for the respective groups when the animals were finished in the feedlot. These findings contrast with those obtained here, in which a larger percentage of SFA was reported.

As regards the proportion of n-6 and n-3 fatty acids, studies have shown that animals in pasture-based rearing systems have larger quantities of n-3 acids, which are considered beneficial for human health. Although, the animals were reared on pasture, in Nutritional Plan 2, the amount supplied was not sufficient to cause alterations, with n-3 levels reduced to 4.50 and 4.78% for Nutritional Plans 1 and 2, respectively. A number of studies have reported the positive effects of increased n-3 intake for cardiovascular diseases.

SALTER (2013) reported that the n-6:n-3 ratio considered beneficial in beef is low (usually <3), reflecting significant amounts of PUFA, especially those of the n-3 series and mainly linolenic acid (18:3 n-3). The meat from the animals evaluated in our study showed values within the range recommended by health organizations, but near the threshold deemed undesirable for human health. According to the Food and Agriculture Organization - FAO (2010), although, these fatty acids are beneficial for human health, the recommended n-6:n-3 ratio is between 4:1 and 5:1, which is the average found in Brazilian beef.

CONCLUSION

Nutritional plans used in the growing and finishing phases involving low levels of protein-

Table 7 - Proportions (%) of saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), omega-6 (n-6), and omega-3 (n-3) fatty acids and PUFA:SFA and n-6:n-3 ratios in the *longissimus lumborum* muscle of crossbred steers supplemented while on *Brachiaria* (Syn. *Uruchloa*) *brizhantha* cv. Marandu pasture.

Item	---------------Nutritional plan[1]-----------------		CV%	Significance[2]
	1	2		*p*
PUFA	6.75	6.28	38.61	0.6936
MUFA	38.66	37.85	11.00	0.6748
SFA	54.26	55.44	10.10	0.6587
n-6	4.74	4.51	46.04	0.8204
n-3	1.02	0.92	36.75	0.5454
PUFA:SFA	0.12	0.11	45.25	0.7140
n-6:n-3	4.50	4.78	19.00	0.5078

[1]Nutritional Plan 1: mineral mixture *ad libitum* (rainy seasons 1 and 2) + nitrogen/energy supplement at 1 $g.kg^{-1}$ body weight (BW) (dry season); Nutritional Plan 2: nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (rainy season 1) + nitrogen/energy supplement at 2 $g.kg^{-1}$ BW (dry season) + nitrogen/energy supplement at 1 $g.kg^{-1}$ BW (rainy season 2); [2](p) significant if $p<0.05$, not significant if $p>0.05$, at the 5% probability level by the F test.

energy supplementation do not lead to changes significant in carcass characteristics or centesimal composition and fatty acid profiles of the *longissimus lumborum* muscle. Therefore, Nutritional Plan 1 is the most appropriate supplementation to be used in the growing and finishing phases of crossbred cattle because it presents a lower cost.

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BIOETHICS AND BIOSSECURITY COMMITTEE APPROVAL

This study was conducted in conformity with the Brazilian legislation on experimentation involving animals adopted by the National Council of Experimental Control (CONCEA) and was approved by the Ethics Committee on Animal Use (CEUA) of Southwest Bahia State University, Itapetinga - Bahia, Brazil. Protocol 15/2012.

DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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