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ANIMAL SCIENCE

Levels of energy supplementation for heifers in Tifton 85 pasture on carcass characteristics, internal organs and meat quality

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Abstract: The objective of this study was to evaluate the effect of different levels of concentrate supplementation on carcass characteristics of heifers finished on Tifton 85 pasture. Thirty-two cross-breed heifers (Charolais and Nellore) on average aged 25.51 months and weighing 298 kg were used in a completely randomized experiment. The animals were distributed uniformly to receive four different levels of concentrates based on the body weight: 0.0; 0.4; 0.8 and 1.2%. Animals were slaughtered at 29 months of age. There was increasing linear effect of levels energy supplementation on: slaughter weight, hot and cold carcass weights,hot and cold dressing percentage, thigh thickness, carcass compactness, and L* and b* color values. It was observed quadratic effect of levels of energy supplementation on the percentage of fat in the carcass. Different levels of energy supplementation did not modify the accumulation of vital organs and visceral fat or the sensory attributes of the meat. Higher levels of energy supplementation promote increases in carcass traits of heifers when finished on Tifton 85 pasture.

Key words: carcass weight, fat, grass-finishing, meat quality, vital organs.

INTRODUCTION

In Brazil, bovine females represented 39.35% of slaughtering, with 78.15% of cows and 21.85% of heifers in 2016. In the first six months of 2017, heifers accounted for 29.09% of the total number of bovine females slaughtered in Brazil (IBGE 2017). Most of the heifers slaughtered are culled due to two main reasons: reproductive problems (they do not become pregnant in the first mating season), and a high surplus of replacement females.

One of the ways to add value to culled heifers is to slaughter these animals, and give the beef industry a unique product in terms of meat quality, in relation to adult cows. Therefore, producers may adopt technologies, such as the use of cultivated pasture and supplementation with concentrated feeds to achieve this goal. Among the alternatives of forage resources to increase animal production in pastoral systems, Tifton 85 (*Cynodon* spp.) stands out for its high productivity, forage nutritive value, positive response to fertilizer use (Quaresma et al. 2011) and excellent adaptability to the tropical, and subtropical climates (Taffarel et al. 2014).

The use of energetic supplementation for finishing cattle in tropical pasture system have shown positive effects on carcass characteristics, such as higher carcass weight (Baroni et al. 2010), higher carcass yield, and higher level of fat deposition (Rezende et al. 2012, Menezes et al. 2014). However, these trials were conducted with steers, and there is a gap in the literature about their effects in the carcass and meat of heifers.

Cattle slaughtering produces, in addition of the carcass, the so-called non-carcass components. Owens et al. (1993) pointed out that vital organs like those are of greater interest because of their importance in metabolism and nutritional requirements. Meanwhile, Vaz et al. (2015) classify them, among the non-carcass components, like the ones that provide the highest remuneration to the slaughterhouse in Brazil. Thus, the objective of this study was to evaluate the effect of increasing levels of energy supplementation on the carcass characteristics, non-carcass components, and on beef quality of heifers finished on Tifton 85 pasture.

MATERIALS AND METHODS

The procedures adopted in this study were certified by the Ethics Committee on Animal Use (CEUA\UFSM protocol 6976300415). The experiment was carried out between December 19th, 2015 and April 09th, 2016, at the Beef Cattle Laboratory, belonging to the Department of Animal Science of the Federal University of Santa Maria (UFSM), located in the municipality of Santa Maria, Rio Grande do Sul, Brazil (longitude 53°42' W, latitude 29°43' S, altitude 95 m). The climate of the region is Cfa (subtropical humid), according to the Köppen classification (Alvares et al. 2013). The soil of the experimental area catalogued by the São Pedro mapping unit, is classified as paleudalf soil (Embrapa 2013).

The experimental area were a 4.8 ha of perennial Tifton 85 (*Cynodon* spp.) grass pasture, implanted eight years ago, and divided into 16 paddocks of 0.30 ha each. Fertilization of the pasture was done based on soil analysis interpretation, which was collected before the beginning of the experiment. The basal fertilization consisted of two applications of NPK fertilizer formula 5-20-20, on December 12th and February 13th in amounts of 64 kg ha^{-1}. Nitrogen fertilization was accomplished in three equal parts, with 28.80 kg of nitrogen ha^{-1}, in the form of urea, on dates of December 19th, January 16th and March 14th.

Thirty-two heifers, belonging to the experimental beef cattle herd of UFSM, aged 25.51 ± 0.53 months and weighing on average 298 ± 21.49 kg, originating from the crossbreeding of Charolais and Nellore. Prior to the experimental period, the heifers were adapted to paddocks and supplementation for 21 days, when endoparasite control was done by subcutaneous application of Levamisole Phosphate (4.5 mg kg^{-1} body weight). The experimental design was completely randomized, with four treatments and eight replicates, with the animal as experimental and observational unit.

Each treatment consisted of a paddock with two heifers (assuming 0.8 LU for heifers ≈1.6 LU/0.3 ha), replicated four times (n = 8) balanced for breed and initial weights. The adopted grazing method was continuous with variable stocking rate, utilizing regulator animals to maintain the desired forage availability. The heifers were distributed in the following treatments, according to the level of supplementation: without supplementation; 0.4%; 0.8% and 1.2% of supplementation, relative to body weight, based on dry matter. The supplement was provided once a day at 11:00 AM, with 50 cm of feed area regarding each heifer. All treatments had unrestricted access to water in drinking fountains and mineral supplementation, consisting of sodium chloride and dicalcium phosphate. The supplement was formulated based on the NRC (2000) in order to elevate the energy level of the total diet, keeping it isonitrogenous and isoenergetic. Supplement was made of 81.1% white oat grain; 17.0% ground corn grain; 1.5% calcitic limestone and 0.4% urea (Table I). For sampling of apparently forage consumed, grazing simulations were carried out during the experimental period, according to the technique described by Euclides et al. (1992). Forage samples of the simulated grazing and ingredients of supplement, were predried in a forced-ventilation oven at 55 °C, until reaching constant weight, and ground in a Willey mill through a 1 mm mesh sieve for determined for chemical composition (Table I).

Forage mass was determined by the double-sampling technique (Wilm et al. 1944), at the beginning of the grazing period and then every 14 days. The estimation of daily accumulation rate of pasture dry matter was performed every 14 days by using three cages of grazing exclusion per paddock according to Klingmann et al. (1943). Residual pasture mass were pre-determined of 5000 kg MS ha^{-1}. The mean forage offered during the experiment was 12.50; 10.80; 10.90 and 12.00 kg 100 kg^{-1} body weight, based on the dry matter, respectively for: 0.0; 0.4; 0.8 and 1.2% of supplementation, while the leaf blade supply was 1.84; 1.97; 1.86 and 1.76 kg 100 kg^{-1} body weight, in the same order as above.

After 120 days of experimental period, heifers were sent to slaughter, coinciding with the end of the vegetative cycle of the Tifton 85 pasture. Prior the shipment to slaughterhouse, heifers were weighed after fasting for 14 hours of solids and liquids, to obtain the slaughter weight. Heifers were slaughtered in a commercial abattoir located in Santa Maria, Brazil (30 km away from the research facility), following slaughterhouse's procedures. During the slaughter all non-carcass components of the heifers were individually separated and weighed and consisted of: peripheral components, vital organs, empty digestive tract, internal fats and blood. The sum of these components, together with the hot carcass weight constitutes the empty body weight (EBW).

At the end of the slaughter line, before entering the cooling chamber, the carcasses were sectioned, identified and weighed to obtain the hot carcass weight. After 24 hours of cooling in a cold chamber, half-carcasses were weighed again to obtain the cold carcass weight. The dressing percentage were calculated

Table I. Chemical composition of ingredients of supplement and grazing simulations in eachtreatment over the experimental period.

Chemical composition (% DM) Ingredients							
	#DM	**OM**	**CP**	**NDF**	**ADF**	**EE**	**IVDOM**
White oat	90.20	97.41	13.15	16.44	5.86	6.73	85.42
Corn	88.89	98.41	8.25	10.14	1.87	4.77	96.77
Grazing simulation	#DM	OM	CP	NDF	ADF	EE	IVDOM
without supplementation	33.10	92.60	12.10	78.70	39.63	1.22	51.30
0.4% BW	33.50	9250	12.20	78,80	39.56	1.16	52.60
0.8% BW	33.08	92.70	12.40	78.80	38.82	1.30	53,33
1.2% BW	33.30	92.60	12.07	79.72	40.10	1.09	52.40

 # Percentage of natural matter; DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; EE = Ether extract; IVDOM = *In vitro* digestibility of organic matter; BW = Body weight.

as the rate between hot or cold carcass and pre-slaughter weight. The cooling loss represented relative weight loss of the cold carcass relative to the hot carcass. The left half of the carcass was cut and separated into three primary cuts: forequarter, hindquarter and sidecut. Those cuts were weighed to calculate their relationship to the entire cold carcass.

The pH index was measured on the *Longissimus dorsi* muscle at the 12th rib, using a digital pH measurement instrument (Testo 205®). From the right half-carcass, the following metric characteristics were obtained: carcass length, measured from the medial cranial border of the first rib and the anterior border of the pubic bone and thickness of the thigh, measured between the lateral and medial surfaces of the upper portion of the thigh, using a compass (Müller 1987). The compactness was calculated as the quotient between the cold carcass weight and the carcass length.

After measuring the metric characteristics, the right half-carcass was sectioned at the 12th rib, aiming to expose the *Longissimus dorsi*, to trace its contour in tracing paper, which was later determined, using a digital scanning table and the Corel Draw software to determine the area of the figure. In addition, the subcutaneous fat thickness was measured as the average of three observations. After 30 minutes of exposure to oxygen, the meat color was measured in the *Longissimus dorsi*, the parameters evaluated were: lightness (L*), redness (a*), and yellowness (b*) which were assessed by the CIE L* a* b* color system, using a colorimeter (Minolta Chroma Meter CR-300, Osaka, Japan). In this moment the degree of the meat marbling was also subjectively determined according to Müller (1987).

To determine the carcass tissue composition, a methodology adapted from Hankins & Howe (1946) was followed, and a section between the 10th and 12th ribs was removed for dissection and prediction through equations of muscle, adipose and bone tissues in the carcass. After dissection, the *Longissimus dorsi* portion was vacuum packed and frozen at - 18°C for further determination of meat quality characteristics.

From the frozen *Longissimus dorsi* muscle, two 2.5 cm thick slices ("A" and "B") were removed. The two slices were thawed for 24 hours, with controlled temperature between 2 and 5 °C. Slice "A" was weighed while still frozen and after thawing to determine the loss of liquid during the thawing process and then was cooked to an internal temperature of 71°C (monitored with a thermometer) to evaluate the loss of liquid during cooking. The same slice "A" used for cooking loss determination were used for evaluation of Shear force. Six round cores of meat (1 cm^3), free from visible fat and connective tissue, were cut from each steak, perpendicular to the muscle fibers, and each core was sheared perpendicularly to the fiber direction, using a Warner-Bratzler shear equipment (G-R Manufacturing Company, Manhattan, KS, USA). Sample "B", after a preparation similar to slice "A", was evaluated by a sensorial panel (n = 6) trained for tenderness, palatability, and succulence (Müller 1987).

The collected data were subjected to the investigation of outliers, by studentized residual method and tested for residues normality by the Shapiro-Wilk test. Subsequently, data were analyzed by ANOVA at 5% level of significance, using, using the GLM procedure of SAS (*Statistical Analysis System*, SAS Studio University Edition, version 3.5). For the response variables with significant effect for the level of supplementation, their means were compared by the Tukey test with $\alpha = 0.05$.

The mathematical model used in the analysis of variance was the following:

$$Y_{ijk} = \mu + LS_j + \varepsilon_{ijk}$$

In which: Y_{ijk} = dependent variables; μ = overall mean of the response variable; LS_j = effect of *j*-th level of supplementation (j = 1, 2,...4); and ε_{ijk} = random effects associated to observation Y_{ijk} assuming normal distribution, independent and identically distributed – NIID (0, σ^2).

After finding significant differences, the polynomial regression analysis was performed using the REG procedure according to the following mathematical model:

$$Y_{ijk} = \beta_0 + \beta_1 X_i + \beta_2 X^2 + \alpha_{ijk} + \varepsilon_{ijk}$$

In wich: Y_{ijk} = observation of dependent variables; β_0 = constant of the estimated equation; β_{12} = estimated linear and quadratic regression coefficient; X_i = level of energy supplementation; α_{ijk} = regression deviations; and ε_{ijk} = residual random error.

The dependent variables were submitted to *Pearson* correlation analysis through the CORR procedure. Data analyses were done by using statistical package SAS® (*Statistical Analysis System*, SAS Studio University Edition, version 3.5).

RESULTS AND DISCUSSION

The slaughter weight was influenced by the supplementation levels (Table II). The heifers finished exclusively on Tifton 85 pasture receiving only mineral supplementation presented lower slaughter weight (343.0 kg). There was a linear effect in slaughter weight with the increase in the level of energy supplementation, increasing 47.44 kg for each

Table II. Carcass characteristics of heifers finished in Tifton 85 pasture fed with different levelsof energy supplementation.

Variables	Levels of energy supplementation				SEM	P-value
	0.0%	0.4%	0.8%	1.2%		
[1] Slaughter weight (kg)	343.00	378.75	384.75	404.25	14.21	***
[2] Empty body weight (kg)	297.10	337.05	341.11	357.24	782	***
[3] Hot carcass weight (kg)	181.37	205.15	211.96	222.06	8.21	***
[4] Cold carcass weight (kg)	177.31	200.80	207.55	217.53	8.04	***
[5] Hot dressing (% SW)	52.84	54.09	55.04	55.91	0.08	*
[6] Cold dressing (% SW)	51.65	52.93	53.88	53.79	0.07	**
Hot dressing (% EBW)	61.12	60.84	62.09	62.13	0.82	NS
Cold dressing (% EBW)	59.75	59.55	60.80	60.86	0.79	NS
Chilling loss (%)	2.24	2.11	2.09	2.03	0.11	NS
Subcutaneous fat thickness (mm)	2.37	2.77	2.71	3.15	0.20	NS
Longissimus dorsi area (cm^2)	63.05	67.32	65.61	62.31	3.08	NS

Levels of energy supplementation (as % of body weight); SEM: Standard error of mean; P-value: Probability; SW: Slaughter weight; EBW: Empty body weight. ***P<0.0001; **P<0.01; *P<0.05; NS – Not significant. [1]$\hat{Y}$= 349.22 + 47.44*Energy supplement level (R^2 = 0.59; CV = 7.01%; P<0.0001). [2]$\hat{Y}$= 305.45 + 46.11*Energy supplement level (R^2 = 0.52; CV = 7.95%; P<0.0001). [3]$\hat{Y}$= 185.80 + 32.22* Energy supplement level (R^2 = 0.40; CV = 8.88%; P<0.0001). [4]$\hat{Y}$= 181.68 + 32.02* Energy supplement level (R^2 = 0.40; CV = 8.81%; P<0.0001). [5]$\hat{Y}$= 53.14 + 1.80* Energy supplement level (R^2 = 0.18; CV = 3.27%; P = 0.0186). [6]$\hat{Y}$= 51.96 + 1.84* Energy supplement level (R^2 = 0.21; CV = 3.11%; P = 0.0084).

0.4% BW. A similar response was observed for empty body weight increasing linearly with the inclusion of energy supplementation in the diet of heifers. The correlation among these weights was 0.97 (P<0.0001), which corroborates with the information obtained in the literature (Cattelam et al. 2011). Hot and cold carcass weight also increased linearly with the inclusion of energy supplementation. It should be noted that cold carcass weights of the supplemented heifers were above 180 kg, which is the minimum weight recommended by the Brazilian legislation and accepted by the slaughterhouses for females, even more, when it comes to young animals.

Animals finished exclusively on Tifton 85 pasture produced lighter carcasses when compared with supplemented animals. These carcasses did not reach the minimum weight required by the slaughterhouse industry, which suggests that supplementation is a good option

to increase the carcasses weight. Higher carcass weights give the cattlemen more income per animal, besides the possibility of an extra bonus from the industry. In addition, the slaughterhouse industry is more interested in this product, because it increases the muscle yield and reduces the fixed operating costs.

The increase in the slaughter weight, empty body and carcass weights were due to the higher energy diet intake, which granted the animals greater weight gains throughout the experiment and consequently a higher final weight. As in the present study, Baroni et al. (2010) observed a linear increase in carcass weight when using increasing levels of supplementation in the diet of steers grazing *Brachiaria brizanta* cv. Marandu. The results of our study agree with Lage et al. (2012), who also observed similarities in hot and cold carcass weights for heifers fed with 0.8 and 1.2% of body weight of concentrate.

Hot and cold dressing percentage increased linearly with inclusion of energy supplementation for heifers, finishing in Tifton 85 pasture. Table I shows the values of *in vitro* digestibility of the organic matter, both for the ingredients of the supplement and for the forage offered by the heifers. It is observed that the digestibility of the supplement was quite higher than the forage. Therefore, it is speculated heifers that received supplement in greater quantity consumed a diet with a higher passage rate through the gastrointestinal tract, in relation to those that were not supplemented. The longer dwell time of the digesta in the heifers without supplementation resulted in a higher gastric content, reducing the cold carcass yield, when compared to those supplemented, as evidenced by the similarity between hot and

cold dressing percentage, for all levels, when adjusted to the empty body weight (Table II).

However, Lage et al. (2012) obtained higher hot and cold dressing percentage for heifers that consumed 0.8% BW, in relation to those fed with 1.2% BW, justifying the lower yield of those that consumed more concentrate by the increase of viscera and internal fats.

The loss of fluid, represented by the loss of fluid of the carcass in cold chamber, was similar among the evaluated supplementation levels (P>0.05), which is closely associated with the thickness of subcutaneous fat that was also similar among the treatments, because fat thickness works as a thermal insulation preventing loss of liquid by dripping. The correlation between subcutaneous fat thickness and chilling loss variables was negative (r=-0.37; P=0.0463). The values obtained in this study are close to those in the study by Lage et al. (2012), who verified a mean of 2.01% for heifers supplemented with 0.8 and 1.2% of body weight.

The subcutaneous fat thickness was similar among the different levels of supplementation (P>0.05), and only the heifers receiving supplementation at the level of 1.2% presented adipose tissue deposition within the limits recommended by the Brazilian slaughterhouses (between 3 and 6 mm). The supply of leaf blades from pasture, described in the material and methods, may have been limited in all treatments, thus, the heifers were not able to select parts of the forage with higher digestibility, which negatively influenced the subcutaneous fat. The portion of green leaves in the pasture tends to present greater nutritional value, in comparison with other plant's components, and they may even enhance the use of concentrated foods.

When producing heifers for slaughter in sorghum pasture with 1% of BW in energy supplementation, Rodrigues et al. (2017) observed back fat thickness within the standards required by the slaughterhouses. The animals of their study were from the same genetic composition as those of our study, but younger. Nevertheless, the supply of leaf blades verified by these authors was superior to the one found in our study, justifying the importance of pasture managing, to allow the selection of high quality parts of the plant.

The *Longissimus dorsi* area was similar among the treatments (P>0.05), and higher values for this characteristic are desired, as it is related to the greater muscularity in the carcass. Similar result was observed for primary cuts were expressed in relation to 100 kg of cold carcass, they were similar among the supplementation levels (P>0.05).

Greater percentage of sidecut is expected when subcutaneous fat thickness is high, since in this region of the bovine body there is a more intense deposition of adipose tissue. However, in the present study, the increase in the level of energy supplementation was not enough to raise the cover fat (Table II) and consequently the percentage of rib in the carcass (Table III). Greater contributions from the rear cut are relevant, especially for the slaughterhouses, since the main cuts and better prices are found in this portion of the carcass (Missio et al. 2010).

The carcass length was similar among the treatments (Table III), which is related to the similarity in genetic composition, age of the heifers and the equality of the finishing period, without being influenced by the diets. The length of the carcass could be altered by modulations in the heifer's bone growth, but the participation of this tissue in the carcass was similar (Table IV), justifying this response. The differences in cold carcass weight, along with the similarity in carcass length, reflected an increase linearly in carcass compactness (Table

Table III. Weight and yield of cuts forequarter, sidecut and hindquarter, carcass length, carcasscompactness and thigh thickness of heifers finished in Tifton 85 pasture, receiving increasing levels of supplementation.

Variables	Levels of energy supplementation				SEM	P-value
	0.0%	0.4%	0.8%	1.2%		
Forequarter (%)	36.82	36.65	36.29	36.28	0.26	NS
Sidecut (%)	10.95	11.55	11.66	11.91	0.22	NS
Hindquarter (%)	52.17	51.85	52.26	52.46	0.15	NS
carcass length (cm)	120.81	123.81	122.56	124.43	0.89	NS
[1] Thigh thickness (cm)	22.43	23.93	25.43	24.83	0.57	**
[2] Compactness (kg/cm)	1.51	1.65	1.72	1.77	0.04	***

Levels of energy supplementation (as % of body weight); SEM: Standard error of mean; P-value: Probability;SW: Slaughter weight; EBW: Empty body weight. ***P<0.0001; **P<0.01; *P<0.05; NS – Not significant. [1]$\hat{Y}$= 22.85 + 2.17*Energy supplement level (R^2 = 0.37; CV = 0.83%; P<0.0001). [2]$\hat{Y}$= 1.54 + 0.22*Energy supplement level (R^2 = 0.48; CV = 0.86%; P<0.0001).

III). Higher carcass compactness indices are interesting because this parameter indicates the meat storage capacity in the carcass. In our study, this indicator increased from 0.21 and 0.26 kg/cm, respectively, to the levels 0.8 and 1.2% BW of supplement, in relation to non-supplemented heifers.

The thigh thickness presented similar behavior to the compactness as the supplementation levels increased, and the correlation among these variables was positive (r=0.55; P=0.0011). This result agrees with the one found by Menezes et al. (2014), who verified a linear increase in the thigh thickness with the increment in the level of supplementation of steers in tropical pasture. The authors stated that the additional energy, supplied via concentrate, was used for greater muscle deposition, a response similar to that verified in our study. Increases in the thigh thickness are interesting, mainly to the slaughterhouse industry, because this region of the body has the cuts with greater commercial value. Thus, by providing high levels of concentrate for heifers finished in Tifton 85 pasture, the size of the noble cuts may be increased.

Regarding the tissue composition of the carcass (Table IV), only fat deposition was influenced, with quadratic adjustment of the regression equation according to the increase of levels energy supplementation.

Although higher fat participation in the carcass of heifers that received the highest level of concentrate (1.2% BW) was expected, this result was not observed. It is speculated that the greater slaughter weight of heifers supplemented with 1.2% BW (Table II), made them more demanding, reducing the efficiency of fat deposition in the carcass. Add to this the fact that heifers of treatment 1.2% BW had the lowest supply of leaf blades, since it was recommended to maintain a similar total forage supply among the groups. Thereby, the maximum fat deposition point in the carcass occurred with 1.14% BW of energy supplementation. Changes in the physical composition of the carcass are expected when higher levels of energy are provided, increasing the amount of deposited

Table IV. Composition of muscle, adipose and bone tissues in the carcass and internal organs of heifers finished in Tifton 85 pasture, receiving increasing levels of supplementation.

Variables	Levels of energy supplementation				SEM	P-value
	0.0%	0.4%	0.8%	1.2%		
Muscle (%)	68.02	62.67	62.56	65.26	1.57	NS
[1] Fat (%)	15.81	20.98	20.97	20.29	1.43	*
Bone (%)	16.17	16.35	16.47	14.45	0.58	NS
Muscle: bone	4.12	3.88	4.04	4.33	0.19	NS
Muscle + fat: bone	5.08	5.17	5.47	5.69	0.24	NS
Heart (% EBW)	0.33	0.33	0.31	0.34	0.02	NS
Lung (% EBW)	1.64	1.38	1.48	1.40	0.13	NS
Liver (% EBW)	0.88	1.01	0.93	1.03	0.11	NS
Kidney (% EBW)	0.17	0.19	0.19	0.18	0.08	NS
Visceral fat (% EBW)	3.76	4.21	4.45	4.25	0.19	NS

Levels of energy supplementation (as % of body weight); SEM: Standard error of mean; P-value: Probability;SW: Slaughter weight; EBW: Empty body weight. ***P<0.0001; **P<0.01; *P<0.05; NS – Not significant. [1]$\hat{Y}$= 16.02 + 4.52*Energy supplement level – 1.98*Energy supplement level^2 (R^2 = 0.27; CV = 19.33; P=0.0150).

fat (Pethick et al. 2004). These authors cite that addition of fat to any deposit is the sum of the synthesis and degradation of triacylglycerol, which require non-esterified fatty acids (NEFA) and glycerol. Glycerol is derived from glucose but the NEFA can be obtained from a variety of sources including de novo synthesis from glucose, lactate or acetate and they can be acquired as pre-formed fatty acids in the diet delivered to the fat deposit as lipoprotein (Pethick et al. 2004). Therefore, the use of supplementation enabled the supply of these precursors of triacylglycerols, with greater fat deposition in the carcass of the supplemented heifers.

In contrast, to the results of present study, Menezes et al. (2014) found a higher percentage of muscle in non-supplemented steers (65.5%) than for the steers supplemented with 0.5 and 1.0% BW (59.6 and 59.5%, respectively). In our study, there was a trend of greater relative muscle participation for non-supplemented heifers (P= 0.0639). This result occurs because the increase in the participation of one tissue reflects in the reduction of another, since they are expressed in relative values (Menezes et al. 2014).

The supplemented heifers presented a relative participation of muscle, bone and adiposetissues, with values consistent with those observed by Kazama et al. (2008), who evaluated crossbred ½ Angus ½ Nelore heifers, with age similar to those of our study, but in feedlot. Therefore, the need for supplementation for heifers of this age group is reinforced, because, when they are produced exclusively in Tifton 85 pasture, there was proportionally less fat in the carcass, even with less participation of this tissue in relation to the bone.

Muscle: bone and muscle + fat: bone ratios were not influenced by supplementation levels (P>0.05). In the evaluation of the bovine carcass composition, the muscle: bone ratio is probably the most important characteristic, since it represents a greater amount of the most desired tissue, in detriment to the tissue not used by the human consumer (Alves Filho et al. 2016).

The set of vital organs, represented by heart, lung, liver and kidneys, were expressed in relation to empty body weight, being similar among levels of supplementation (P>0.05). Thus, the increase in supplementation levels may not provide a significant increase in the basal metabolic rate, in a way that could alter the relative mass of these organs. For Almeida Júnior et al. (2008) it is expected that cattle fed with high energy densities will have greater development of vital organs, in the same weight of empty body, to meet the most intense energy metabolism. This fact can be verified when comparing our results with those of Krueger et al. (2010), who evaluated bulls fed with a high-grain diet in feedlot, and obtained higher values for heart, liver and kidneys, expressed in relation to the empty weight.

Among the vital organs, the liver can be considered as the most relevant, since according to Owens et al. (1993), it actively participates in the nutrients metabolism, triggered by food consumption, energy requirements and metabolic rate. In addition, among the red viscera, the liver represents the most important product of added value in the slaughterhouse industry (Vaz et al. 2015). When extrapolating to absolute weight, from the relative weight (% EBW), it is verified that, on average, the livers weighed 2.73; 3.43; 3.26 and 3.72 kg, respectively, for heifers with 0.0; 0.4; 0.8 and 1.2% supplementation. Heavier livers are associated with higher slaughter weight, thus, heavier slaughtered heifers, and in addition to generating carcasses with higher weights, generate also larger non-carcass components of commercial added value for the industry.

There was similarity in the participation of visceral fats in the empty body weight of heifers (Table IV). This response conflicts with Missio et al. (2009), who verified a linear increase in the deposition of cavity fats as the concentrate was increased in the diet, nevertheless evaluating confined cattle. Like the vital organs, increased visceral fats are responsible for increasing the cattle nutritional requirements, which is in accordance with the data of our study. In addition, these components reduce the carcass yield. For the slaughterhouse industry, Vaz et al. (2015) report that visceral fats are not interesting because they have little representativeness in remuneration, in relation to other non-carcass components. In contrast to this, it must be considered that, the fat deposition in the body of the animal has priority sites of accumulation, and the first one is represented by the visceral fats. Therefore, when looking for larger amounts of adipose tissue covering the carcass and interspersed in the meat (marbling), there will be a higher deposition of visceral fat.

The meat pH was not influenced by the levels of supplementation (Table V), being within the range considered ideal in bovine meat, which, according to Mach et al. (2008), is between 5.4 to 5.8, 24h after slaughter. The pH values are also justified by the adequate management used in the pre-slaughtering of heifers, since a stressing management during this period can lead to excessive expenditure of muscle glycogen, exhausting the reserves that would later be used to establish rigor mortis and drop the muscle pH.

Marbling fat was not influenced by supplementation levels (P>0.05), which is classified as traces for heifers without supplementation, and as slight for supplemented females. Due to the genetic composition of the heifers, abundant marbling was not expected. The higher levels of supplementation were not able to promote digestible energy consumption sufficiently superior to the point of interfering in the deposition of marbling fat, which is explained by the fact that the fat covering was similar among the groups (Table II).

Meat coloration was influenced by the supplementation levels, in the L* and b* values, which increased linearly with the inclusion of energy supplement in diet of heifers. However, the values of a* (red intensity) were not influenced by supplementation levels. Higher L* values indicate meat with brighter coloring. The values of L* are related to the values of b* and the lipid content in the meat (Luciano et al. 2009). In this study, the correlation coefficient between b* and L* was 0.96 (P<0.0001). Therefore, the termination only in pasture reduces the fat deposition and decreases the values of b* and L*.

The meat coloring is the first attribute to be considered by the consumer when choosing the meat product. In this case, the energy supplementation along with Tifton 85 grazing canbe used as an alternative to improve the meat visual appearance, making it more attractive to the consumer.

The meat from the heifers supplemented at different levels and grazing Tifton 85 had similar values for fluid losses in thawing and cooking (Table V), which may be associated with the similarity in the meat marbling degree. These results disagree with those obtained by Menezes et al. (2014), who verified a linear increase in cooking loss with the increment of the supplementation, nevertheless the authors report that the marbling has a negative association with the thawing and a positive association with the cooking losses.

The meat tenderness was not influenced by the supplementation levels, either by the

Table V. Qualitative characteristics of the meat, measured in the *Longissimus dorsi* muscle ofheifers finished in Tifton 85 pasture, receiving increasing levels of supplementation.

Variables	Levels of energy supplementation				SEM	P-value
	0.0%	0.4%	0.8%	1.2%		
pH24h	5.66	5.53	5.53	5.56	0.89	NS
[I] Marbling (points)	3.87	5.00	4.75	5.25	0.97	NS
[1] Lightness (L*)	28.91	32.32	33.43	33.04	1.11	*
Redness index (a*)	10.66	12.74	13.60	13.20	0.93	NS
[2] Yellowness index (b*)	3.98	5.44	6.04	5.56	0.49	*
Thawing loss (%)	10.45	10.20	9.50	8.27	1.72	NS
Cooking loss (%)	25.72	27.20	21.42	20.75	2.12	NS
Shear Force (KgF/cm^3)	5.99	5.49	4.20	5.40	0.84	NS
[II] Tenderness (points)	6.28	6.57	6.24	6.37	0.38	NS
[II] Palatability (points)	6.39	6.04	6.26	6.57	0.19	NS
[II] Succulence (points)	6.28	6.37	6.24	6.35	0.30	NS

[I] Scale from 1 to 18 points, being: 1 - 3 traits; 4 - 6 slight; 7 - 9 small; 10 - 12 medium; 13 - 15 moderate; 16 – 18 abundant; [II] Scale from 1 to 9 points, being: 1 = extremely tough, extremely tasteless, or extremely non-succulent; 2 = very tough, lacking in flavor, or lacking in succulence; 3 = tough, low taste, or low succulence; 4 = slightly below average; 5 = average; 6 = slightly above average; 7 = tender, tasty, or succulent; 8 = verytender, very tasty, or very succulent; 9 = Extremely tender, extremely tasty, or extremely succulent. Levels of energy supplementation (as % of body weight); SEM: Standard error of mean; P-value: Probability;SW: Slaughter weight; EBW: Empty body weight. ***P<0.0001; **P<0.01; *P<0.05; NS – Not significant. [1]$\hat{Y}$= 29.30 + 3.37*Energy supplement level (R^2 = 0.24; CV = 10.01%; P=0.0122). [2]$\hat{Y}$= 11.27 + 2.12*Energy supplement level (R^2 = 0.15; CV = 26.31%; P=0.0261).

objective method, through the shear force, or by the sensorial evaluation, performed by the taste panel. The mean value of 5.27 kgF/cm^3 is adequate for softness, considering the age of29 months at slaughter, the participation of zebu genotype in the racial composition of the heifers, and the presence of the *calpastatin* enzyme. Thus, it can be emphasized that although the carcasses presented low fat thickness, this fact did not compromise the meat tenderness. Inthe study by Comparin et al. (2013), with Brangus heifers with similar age to the ones of our study, and supplemented in *Brachiaria brizantha* cv. Marandu pasture, there was no effect of supplementation on shear force. However, the average value obtained by these authors was 8.35 kgF/cm^3, which represents a less tender meat than those verified in our research.

The meat tenderness was considered as slightly above the average, with 6.36 points by the sensory evaluation. Therefore, the use of Tifton 85 pasture may be considered, whether associated with supplementation or not, when it is sought to produce meats that meet the consumer's desires, aiming to provide the feeling of softness. Other sensorial aspects that the consumer assents to are the beef palatability and juiciness. In this study, there was no effect of supplementation on these characteristics, which were considered slightly above the average. With confined young bulls, Missio et al. (2010) did not verify the effect of the inclusion of concentrate on the diet regarding palatability and succulence, with values also considered above the average. The palatability showed a positive correlation with the degree of marbling (r= 0.59; P= 0.0159), which confirms Thompson (2002) statement that marbling is extremely important in the meat palatability, explaining 10 to 15% of its variation. This variation can be explained by additive factors such as genetics, maturity, *ante* and *post* mortem management, as well as processing techniques of carcass and meat.

CONCLUSIONS

Higher levels of energy supplementation in the diet for heifers finished on Tifton 85 pasture provides an increase in carcass weight when compared with those non-supplemented, but without altering the yield of the primary cuts.

Supplementation did not alter sensory properties of beef. However, beef from supplemented heifers presented better coloring appearance.

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REFERENCES

ALMEIDA JÚNIOR GA, COSTA C, CARVALHO SMR, PANICHI A & PERSICHETTI JÚNIOR P. 2008. Características de carcaças e dos componentes não-carcaça de bezerros holandeses alimentados após o desaleitamento com silagem de grãos úmidos ou grãos secos de milho ou sorgo. Rev Bras Zootec 37: 157-163.

ALVARES CA, STAPE JL, SENTELHAS PC, GONÇALVES JLM & SPAROVEK G. 2013. Köppen's climate classification map for Brazil. Meteorol Z 22: 711-728.

ALVES FILHO DC, BARCELLOS JOJ, ZAGO D, SARTORI EV, ANTUNES KK & ANDRADE NT. 2016. Características de carcaça de novilhos terminados em confinamento com inclusão parcial na dieta de silagem de girassol. Arch Latinoam Prod Anim 23: 139-148.

BARONI CE, LANA RP, MANCIO AB, QUEIROZ AC, LEÃO MI & SVERZUT CB. 2010. Níveis de suplemento à base de fubá de milho para novilhos Nelore terminados a pasto na seca: desempenho, características de carcaça e avaliação do pasto. Rev Bras Zootec 39: 175-182.

CATTELAM J, FREITAS LS, BRONDANI IL, SILVA JHS, ARBOITTE MZ & WEISE MS. 2011. Características dos componentes externos e das gorduras descartadas de novilhos superprecoces não castrados ou castrados de dois genótipos terminados em confinamento. Rev Bras Zootec 40: 1774-1780.

COMPARIN MAS, MORAIS MG, ALVES FV, COUTINHO MAS, FERNANDES HJ, FEIJÓ GLD, OLIVEIRA LOF & COELHO RG. 2013. Desempenho, características qualitativas carcaça e da carne de novilhas Brangus suplementadas em pastagem recebendo diferentes aditivos nutricionais. Rev Bras Saúde Prod Anim 14: 574-586.

EMBRAPA. 2013. Empresa Brasileira de Pesquisa Agropecuária. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação de solos. 3ª ed. Brasília: EMBRAPA; Brasília, Brazil, 353 p.

EUCLIDES VPB, MACEDO MCM & OLIVEIRA MP. 1992. Avaliação de diferentes métodos de amostragem sob pastejo. Rev Bras Zootec 21: 691-702.

HANKINS OG & HOWE PE. 1946. Estimation of the composition of beef carcasses and cuts (Technical Bulletin, USDA n. 926). Washington, U.S.A. p 21.

IBGE. 2017. Instituto Brasileiro de Geografia e Estatística. Indicadores IBGE – Estatística da produção pecuária. Avaliable in: <ftp://ftp.ibge.gov.br/Producao_Pecuaria/Fasciculo_Indicadores_IBGE/abate-leite-couro-ovos_201702caderno.pdf>. Accessed 15 December 2017.

KAZAMA R, ZEOULA LM, PRADO IN, SILVA DC, DUCATTI T & MATSUSHIDA M. 2008. Características quantitativas e qualitativas da carcaça de novilhas alimentadas com diferentes fontes energéticas em dietas à base de cascas de algodão e de soja. RevBras Zootec 37: 350-357.

KLINGMANN DL, MILES SR & MOTT GO. 1943. The cage method for determining consumption and yield of pasture herbage. J Am Soc Agron 35: 739-746.

KRUEGER WK, GUTIERREZ-BAÑUELOS H, CARTENS GE, MIN BR, PINCHACK WE, GOMEZ RR, ANDERSON RC, KRUEGER NA & FORBES TDA. 2010. Effects of dietary tannin source on performance, feed efficiency, ruminal fermentation, and carcass and non-carcass traits in steers fed a high-grain diet. Anim Feed Sci Technol 159: 1-9.

LAGE JF, PAULINO PVR, VALADARES FILHO SC, SOUZA EJO, DUARTE MS, BENEDETI PDB, SOUZA NKP & COX RB. 2012. Influence of genetic type and level of concentrate in the finishing diet on carcass and meat quality traits in beef heifers. Meat Sci 90: 770-774.

LUCIANO G, MONAHAN FJ, VASTA V, PENNISI P, BELLA M & PRIOLLO A. 2009. Lipid and colour stability of meat from lambs fed fresh herbage or concentrate. Meat Sci. 82: 193-199.

MACH N, BACH A, VELARDE A & DEVANT M. 2008. Association between animal, transportation, slaughterhouse practices, and meat pH in beef. Meat Sci 78: 232-238.

MENEZES LFG, SEGABINAZZI LR, FREITAS LS, RESTLE J, BRONDANI IL, CALLEGARO AM, JONER G & ALVES FILHO DC. 2014. Aspectos qualitativos da carcaça e carne de novilhos superjovens da raça Devon, terminados em pastagem tropical, recebendo diferentes níveis de concentrado. Semina: Ciênc Agrár 35: 1557-1568.

MISSIO RL, BRONDANI IL, RESTLE J, SILVA JHS, SILVEIRA MF & SILVA VS. 2009. Partes não-integrantes da carcaça de tourinhos alimentados com diferentes níveis de concentrado na dieta. Rev Bras Zootec 38: 906-915.

MISSIO RL, BRONDANI IL, ALVES FILHO DC, RESTLE J, ARBOITTE MG & SEGABINAZZI LR. 2010. Características da carcaça e da carne de tourinhos terminados em confinamento, recebendo diferentes níveis de concentrado na dieta. Rev Bras Zootec 39: 1610-1617.

MÜLLER L. 1987. Normas para avaliação de carcaças e concurso de carcaça de novilhos. 2ª ed. Santa Maria: Universidade Federal de Santa Maria, Santa Maria. Brazil, 31 p.

NRC. 2000. Nutrient requirements of beef cattle. National Research Council. 7th ed., National Academy Press, Washington, U.S.A.

OWENS FN, DUBESKI P & HANSON CF. 1993. Factors that alter the growth anddevelopment of ruminants. J Anim Sci 71: 3138-3150.

PETHICK DW, HARPER GS & ODDY VH. 2004. Growth, development and nutritional manipulation of marbling in cattle: a review. Aust J Exp Agri 44: 704-715.

QUARESMA JP, ALMEIDA RG, ABREU JG, CABRAL LS, OLIVEIRA MA & GUEDES DM. 2011. Produção e composição bromatológica do capim-tifton 85 (*Cynodon* spp) submetido a doses de nitrogênio. Acta Sci Anim Sci 33: 145-150.

REZENDE PL, RESTLE J, FERNANDES JJR, NETO MDF, PRADO CS & PEREIRA MLR. 2012. Carcass and meat characteristics of crossbred steers submitted to different nutritional strategies at growing and finishing phases. Cienc Rural 42: 875-881.

RODRIGUES LS, ALVES FILHO DC, BRONDANI IL, SILVA VS, PAULA PC, ADAMS SM, MARTINI PM & CARDOSO GS. 2017. Effect of planting pattern of forage sorghum on forage productivity and heifer performance during finishing phase. Semina: Ciênc Agrár 38: 1537-1550.

SAS. 2016. SAS Institute Inc. User's guide version 3.5 SAS® Studio University Edition. Ref. Cary, North Carolina, USA.

TAFFAREL LE, MESQUITA EE, CASTAGNARA DD, OLIVEIRA PSR, OLIVEIRA NTE, GALBEIRO S & COSTA PB. 2014. Produção de matéria seca e valor nutritivo do feno do tifton 85 adubado com nitrogênio e colhido com 35 dias. Rev Bras Saúde Prod Anim 15: 544-560.

THOMPSON J. 2002. Managing meat tenderness. Meat Sci 62: 295-308.

VAZ FN, RESTLE J, PÁDUA JT, FONSECA CA, PASCOAL LL & SEVERO MM. 2015. Componentes não carcaça de bovinos Nelore abatidos com diferentes pesos. Ci Anim Bras 16: 313-323.

WILM HG, COSTELLO DF & KLIPPLE GE. 1944. Estimating forage yield by the double-sampling methods. J Am Soc Agron 36: 194-203.

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