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Slaughter weight did not alter carcass characteristics and meat quality of crossbred heifers supplemented and finished in a pasture system

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ABSTRACT. This work was carried out to evaluate the animal performance, carcass characteristics and meat quality of crossbred heifers slaughtered at three different body weights. The heifers were slaughtered with 330 (Light), 360 (Medium) and 400 (Heavy) kg body weight. The final weight, average daily gain and carcass weight were greater for HEA heifers, intermediate for MED heifers and lower for LIG heifers. However, carcass dressing and pH were similar for the three heifers groups. Dripping loss, dissection loss and the muscle, fat and bone percentages on the 6th rib did not alter by slaughter weight. Slaughter weight did not affect the colour, shear force and lipid oxidation of meat. In conclusion, heavy heifers finished in pasture and that were concentrate-supplemented had better animal performance; however, the carcass characteristics and meat quality were similar for the three heifers groups.

Keywords: instrumental analysis, beef cattle, meat, animal production.

Peso de abate não alterou as características de carcaça e qualidade da carne de novilhas mestiças terminadas a pasto com suplementação

RESUMO. Este trabalho foi realizado para avaliar o desempenho animal e características da carcaça e da carne de novilhas mestiças abatidas com três diferentes pesos vivos. As novilhas foram abatidas com 330 kg (LEV), 360 kg (MED) e 400 kg (PES). O peso vivo final, ganho médio diário e peso de carcaça foram superiores para as novilhas PES, intermediário para as novilhas MED e inferiores para as novilhas LEV. No entanto, o rendimento de carcaça e pH foram semelhantes para os três grupos de animais. As perdas por gotejamento, dissecação e as percentagens de músculo, gordura e ossos na 6ª costela não foram alteradas pelos três pesos de abate. Da mesma forma, o peso de abate não teve efeito sobre a coloração, força de cisalhamento e oxidação lipídica da carne. Em conclusão, novilhas mais pesadas terminadas em pastagem e suplementadas com concentrado apresentaram melhor desempeno animal; todavia, as características de carcaça e qualidade da carne não foram alteradas.

Palavras-chave: análise instrumental, peso de abate, novilhas, qualidade da carne.

Introduction

Brazil has the greatest world commercial cattle population with 200 million head, which represents a major contribution to the production and commercial system of the international market (ANUALPEC, 2014).

Among the advantages found in the Brazilian system of beef cattle production, climate characteristics stand out ahead of forage production. However, there are disadvantages of production in the tropical climate region, especially the seasonal changes and periods without rain. During dry periods there is a decrease in the amount and nutritional value of the available forage, directly affecting the performance of animals raised in pasture system (Moreira et al., 2003; 2004).

In Brazil, the heifers slaughtered represent approximatively 5% of the cattle slaughtered for beef production (ANUALPEC, 2014). The heifers finished in feedlot are slaughtered at between 20 and 24 months, with between 180 to 210 kg carcass weight (Marques et al., 2010; Nascimento et al., 2003; Prado et al., 2000a; b). The average daily gain of these heifers varies between 0.70 and 1.20 kg and the hot carcass dressing is from 50 to 54% (Farias et al., 2012; Marques et al., 2000; Nascimento et al., 2003; Prado et al., 2000a; b). However, the average daily weight gain of heifers from system crossbreeding and finished in a feedlot can be superior to 1.50 kg day^{-1} (Macedo et al., 2007; Marques et al., 2000). The feed efficiency of heifers finished in a feedlot may vary from between 6 and 8 kg of dry matter for a gain of 1 kg of body weight, which is close to the observed efficiency of males finished in feedlot (Farias et al., 2012; Marques et al., 2000; Nascimento et al., 2003). In addition, heifers have a better quality of meat compared to the steers and bulls finished on pasture or feedlot (Kazama et al., 2008; Macedo et al., 2007; Rotta et al., 2009) due to their increased sexual precocity.

On the other hand, the price paid to the producer by the marketing system devalues the heifers at slaughter, with the price paid being approximately 90% of that of the gold standard ox, or less. In fact, the meat market in Brazil does not have actual knowledge of the quality of disposal of heifers' meat. However, the weight of slaughter of heifers can vary greatly depending on the finishing system, genetic group, geographic region and market demand (Kazama et al., 2008; Rotta et al., 2009; Wada et al., 2008). Therefore, it is necessary to study the effects of different slaughter weights of the heifers for better appreciation and commercial consideration of the ideal weight.

This study was conducted to evaluate the effects of three different slaughter weights of crossbred heifers on animal performance, carcass characteristics and meat quality.

Material and methods

Local

This experiment was approved by the Department of Animal Production of the State University of Maringá (CIOMS/OMS, 1985) and was conducted at the Rosa and Pedro Sector of the Experimental Station of the Iguatemi Farm at the State University of Maringá, Paraná State, Brazil South.

Animals

Fifty crossbred heifers (Zebu *vs.* European) were used in a completely randomized design. The heifers were weighed and distributed into three weight groups with five replications per group. At the beginning of the experimental period, the heifers were 24 ± 2 months old and weighed 319.1 ± 5.92 kg.

At the end of the experimental period, the heifers were weighed after fasting for 16 hours and classed into three treatments according the following average final weights: Heavy = 400 kg, Medium = 360 kg, and Light = 330 kg.

Management and diets

Before the experimental period, the heifers had a 21-day adaptation period. Heifers were housed in collective pens with 80 m^2 per heifer in *Cynodonn lemfluensis* pasture, equipped with collective feeders 60 cm deep and 20 m long, and drinkers with a capacity of 500 litres of water. The heifers were fed twice a day at 8:00 a.m. and 16:00 p.m. The intake of concentrate and corn silage were recorded daily until day 90 of the experimental period.

At the end of the experimental period, the heifers were weighed and slaughtered at a commercial slaughterhouse 60 km from the experimental farm, in accordance with Brazilian practices.

The concentrate used was based on corn, soybean meal, glycerine, urea, limestone and mineral salt (Table 1). The glycerin was added to increase the energy density of the diet (Eiras et al., 2014a; b). The provided diet had a ratio of 40% forage (corn silage) and 60% concentrate. The diet formulation and quantity supplied were designed to provide a weight gain of 0.7 kg day^{-1}, according to NRC (2000) recommendations.

Animal performance

To determine animal performance, the heifers were weighed once at the beginning of the experiment and then once every 14 days (after fasting from solid food for a period of 16 hours) for the duration of the experiment (90 days).

Table 1. Chemical composition and percentage of ingredients and concentrated supplement used in diets.

	%	DM	OM	Ashes	CP	EE	NDF	ADF	TC	NFC	TDN
Star grass	*Ad libitum*	16.5	91.1	8.90	14.0	1.40	69.3	33.4	76.1	12.8	46.6
Corn silage	40.0	29.1	97.3	2.73	6.06	3.36	87.8	51.4	36.4	19.2	62.2
Soyaben meal	12.0	81.5	92.9	7.14	48.9	2.50	41.5	23.4	18.1	11.6	78.0
Corn cracked	14.9	81.8	97.7	2.32	10.3	5.93	81.4	64.1	17.3	4.77	81.6
Protein supplement	13.0	98.7	48.4	51.6	56.0	16.8					72.0
Glycerine	20.0	94.3	95.2	4.76	0.07	0.12					80.6
Mineral salt[1]	0.11	98.0									
Diet supplement		65.4	89.9	9.95	17.1	4.73	52.2	32.9	19.3	9.78	71.9

[1]Mineral salt mineral, composition by kg: calcium 175 g; phosporus, 100 g; sodium, 114 g; selenium, 15 g; magnesium, 15 g; zinc, 6.004 mg; manganese, 1.250 mg; copper, 1.875 mg; iodine, 180 mg; cobalt, 125 mg; fluorine (maximun), 1.000 mg.

Carcass sampling

After slaughter, the carcasses were labelled and a cut was carried out that followed the vertebral column, yielding two similar halves. These carcasses were chilled for 24h at 4ºC. After chilling, the right side carcasses were used to perform the measurements and sampling of the *Longissimus dorsi* muscle (LM) excised between the 5 and 7th ribs. After measurements of $pH_{(24h)}$, fat thickness, LM area, marbling, texture, and colour, steaks of LM were placed in unsealed plastic bags and frozen immediately for other meat analyses.

Tissue composition

The 6th rib was removed, weighed, and kept frozen (-20ºC) before being thawed and dissected into muscle, fat (subcutaneous and inter-muscular), bone, and other tissues (tendons, fascia, blood vessels), according to Robelin and Geay (1975) methodology.

pH determination

The $pH_{(24h)}$ was measured using a pH Meter Text Model (Tradelab, Contagem, Minas Gerais State, Brazil) and a penetration pH-electrode at the point of the 6th rib on the LM after slaughter $pH_{(0h)}$ and 24 hours later after chilling $pH_{(24h)}$ (Young et al., 2004).

Meat characteristics

Fat thickness, LM area, marbling, texture, and colour were determined on the surface of 6th rib after a cross-sectional cut was performed between the 5 and 7th ribs, 24h post slaughter.

Fat thickness was measured using a caliper to average three points over the LM. The *Longissimus* muscle area was measured using a compensating planimeter that measures the area of irregularly shaped objects.

The meat colour in the Cielab space (CIE, 1986) was assessed using a Minolta CR-400 spectrophotometer (Illuminant D65, observer angle 10°, Konica Minolta Holdings, Osaka, Japan) at 30 min after blooming. Colour coordinates expressed as L^*, a^* and b^* were recorded, where L^* is the lightness of colour whose values range from 0 for black to 100 for white, a^* is red/green value, which ranges from $+a^*$ for red to $-a^*$ for green, and b^* is yellow/blue value, which ranges from $+b^*$ for yellow to $-b^*$ for blue. The chroma (C^*) and hue angle (H^*) indexes were calculated as $C^* = (a^{*2} + b^{*2})^{0.5}$ and $H^* = \tan.^{-1} (b^*/a^*)^*[360°/(2^*3.14)]$ expressed in degrees, according MacDougall (2002) recommendations.

Dripping loss

Dripping loss was performed by measuring the difference between the weight obtained before and after refrigeration for 24 hours (±4ºC).

Lipid oxidation

Samples analysed for thiobarbituric acid reactive substances (TBARS) were obtained from the 10th LM rib after 12 months of freezing. Ten grams of meat were homogenized with 20 mL of 10% (w v^{-1}) trichloroacetic acid using an Ultra-Turrax homogenizer (90 s, 20 000 rpm; Fisher Scientific, Loughborough, UK). The homogenate was centrifuged and the supernatant decanted through a paper filter (Whatman nr 311643, Schleicher and Schuell, Dassel, Germany). Two millilitres of filtrate were mixed with 2 mL TBA reagent (300 mg 2-thiobarbituric acid 100 mL H_2O). The mixture was heated in a water bath for 20 min. to 97°C. After the mixture had cooled to ambient temperature, the extinction was measured at 532 nm. The TBARS values are expressed as milligrams of malonaldehyde (MDA) per kilogram of meat (Botsoglou et al., 1994).

Meat texture

For the texture analysis, the cooked steaks were analysed by using a texture analyser (Stable Micro Systems TAXT Plus; Texture Technologies 15 Corp., Surrey, UK) with a Warner-Bratzler cell, following the principles proposed by Honikel (1998). The meat was cut into rectangular pieces of 1 cm^2 cross-section, perpendicular to the direction of the muscle fibres. Warner-Bratzler shear force (WBSF) was performed on LM from the 6th rib after defrosting. The muscle samples were separated into individual standardized 3.5 cm thick slices, placed in an electric oven, and cooked at a defined internal temperature (72°C). When the endpoint temperature was reached, the samples were removed from the electric oven and maintained at room condition until they equilibrated. The WBSF mechanical properties of the meats were obtained using the texture analyser with a 5.0 kg load cell.

Statistical analysis

The experimental design was completely randomized with three treatments and five replications. All variables were previously submitted to a normality test by the univariate procedure (SAS, 2004). The variables, which were within the normal distribution accepted by the Shapiro–Wilk test at 5% probability, were interpreted by ANOVA (SAS, 2004), and differences were tested by the Tukey test ($p < 0.05$), being the variables measured by following the model: $Y_{ij} = \mu + d_i + e_{ij}$, where Y_{ij} is observation on animal j in group I, μ is mean treatments, d_i is the effect of diet i, 1, 2, and 3, and e_{ij} is the residual error.

Results and discussion

Animal performance and carcass characteristics

According to the study's aim, the initial weight was higher ($p < 0.05$) for heavy heifers, intermediate for medium heifers and lower for light heifers (Table 2). The average daily gain (ADG), final live weight (FLW) and hot carcass weight (HCW) were higher ($p < 0.05$) for heavy heifers, intermediate for mean heifers and lower for light heifers (Table 2). The higher ADG, FLW and HCW for heavy heifers were due the higher initial live weight for these heifers. In general, animals with more weight at the start of feedlot and of similar age showed a greater average daily gain during the finishing period in the feedlot and greater slaughter weight. A similar result was observed for medium heifers in comparison to lighter heifers. The observed weights for the three heifer categories were according to the requirements of the Brazilian market (Abrahão et al., 2006; Macedo et al., 2007; Marques et al., 2006a; Prado et al., 2000b).

Table 2. Animal performance and carcass characteristics of crossbred heifers with different weights of slaughter finished on pasture and supplemented with concentrate.

	Slaughter weights			SEM	p < Values
	HEAVY[1]	MEDIUM[2]	LIGTH[3]		
Initial body weigth, kg	338a	314ab	305b	5.92	0.05
Final body weigth, kg	402a	360b	328c	9.53	0.01
Average daily gain, kg d^{-1}	0.63a	0.45b	0.22c	0.05	0.01
Hot carcass weigth, kg	204a	189b	170c	4.84	0.01
Carcass dressing, %	50.6	52.7	52.0	0.49	0.22
Muscle, %	62.1	61.9	61.6	0.59	0.94
Fat, %	14.7	15.8	15.4	0.58	0.78
Bone, %	17.8	17.2	16.4	0.75	0.76
Others, %	5.34	5.08	6.59	0.68	0.66

[1]Slaughter weight = 400 kg, [2]slaughter weight = 360 kg, [3]slaughter weight = 330 kg, SEM = standard error of mean.

In general, crossbred heifers (*Bos taurus* x *B. indicus*) finished in the feedlot within a similar management regime showed a final body weight of between 320 and 400 kg (Kazama et al., 2008; Marques et al., 2000). Thus, the three heifer groups presented ideal weights for commercialization in the Brazilian market, even the lightest heifers. However, the average daily gain ranged from 0.30 kg for light heifers to 0.70 kg for heavy heifers. The average daily gain can be considered low for grain-supplemented heifers finished in feedlot (Kazama et al., 2008). This low weight gain can be explained by the genetic quality of animals (crossbreeding heifers) and feeding management (supplemented in pasture). Heifers of this genetic quality and supplemented in pasture have a low average daily gain (D'oliveira et al., 1997; Farias et al., 2012).

The hot carcass dressing was similar ($p > 0.10$) for heifers slaughtered at three weights (Table 2). The average carcass dressing was 51.8%. A carcass dressing of about 52% can be considered normal for heifers slaughtered at 24 months, as observed in other studies of heifers slaughtered of a similar weight (Kazama et al., 2008; Marques et al., 2010; Nascimento et al., 2003).

Tissue composition

No differences were observed ($p > 0.10$) for the muscle, fat and bone percentages on the 6th rib in the three categories of heifers evaluated (Table 2). The means percentages for muscle, fat and bone were 62, 15 and 17%, respectively. Other studies carried out with crossbred heifers in feedlot have reported muscle, fat and bone percentages of 56-62, 20-25 and 16-19%, respectively (Kazama et al., 2008; Marques et al., 2006a; b). Thus, the muscle, fat and bone percentages can be considered normal for these animal categories.

Meat characteristics

The pH recorded at slaughter $pH_{(0h)}$ and 24 hours later $pH_{(24h)}$ was similar ($p > 0.10$) for the different slaughter weights (Table 3). The initial pH ranged from 7.2 to 7.3, while 24 hours after chilling the pH ranged from 5.6 to 5.7.

Table 3. Meat characteristics of crossbred heifers with different weights of slaughter finished on pasture and supplemented with concentrate.

	Slaughter weights			SEM	p < Values
	Heavy[1]	Medium[2]	Light[3]		
$pH_{(0h)}$	7.16	7.31	7.16	0.12	0.64
$pH_{(24h)}$	5.64	5.75	5.57	0.03	0.06
Dripping loss, %	0.87	0.92	0.85	0.03	0.68
Desiccation loss, %	1.90	1.77	1.72	0.10	0.77
Fat, mm	7.63	8.96	8.54	0.88	0.74
LM, cm^2 100 kg^{-1}	33.8	31.2	27.6	1.42	0.21

[1]Slaughter weight = 400 kg, [2]slaughter weight = 360 kg, [3]slaughter weight = 330 kg, SEM = standard error of mean.

The $pH_{(24h)}$ observed after chilling met the meat quality standards. pH values below 5.8 indicate that the animals showed stress at slaughter. Thus, the pH can be regarded as normal, assuming that values lower than 5.8 are considered desirable (Abril et al., 2001; Mach et al., 2008).

The dripping and desiccation losses were similar ($p > 0.05$) for the three different slaughter weights (Table 3). The mean dripping loss and desiccation were 0.9 and 1.8%, respectively. In general, dripping loss does not exceed 2% (Hope-Jones et al., 2012) and desiccation is between 2 and 3% (Leygonie et al., 2012).

The fat thickness on the 6th rib was similar ($p > 0.10$) for heifers slaughtered with three different weights (Table 3). The mean fat thickness was 8.4 mm. However, heifers slaughtered between 320 and 400 kg have a fat thickness of between 4.0 and 8.0 mm (Marques et al., 2006b; Wada et al., 2008). The high observed subcutaneous fat thickness content can be directly related to the sex of the animals and their diet (Rotta et al., 2009).

The Longissimus muscle area per 100 kg of carcass (6^{th} rib) was similar ($p > 0.05$) for heifers of the three different slaughter weights (Table 3). The mean Longissimus muscle area was 30.9 cm^2. In general, the Longissimus muscle area from crossbred heifers finished in feedlot ranges from 29 to 31 cm2 per 100 kg of carcass (Kazama et al., 2008; Marques et al., 2006b; Müller et al., 2005).

Meat colour, texture and lipid oxidation

The meat colour was not influenced ($p > 0.05$) by slaughter weights (Table 4). The average value observed for lightness (L*) was 37.4, for redness (a*) was 12.4 and for yellowness (b*) was 12.0. The mean values found for the values of L* and a* are within the range established by Page et al. (2001), who classified meat as dark for L* values below 30 and as light meat when L* is greater than 38. Thus, in this experiment the meat can be classified as clear. In relation to the intensity of yellow (b*), the meat can be classified as less yellow when b* values are below 3.4 and more yellow when b* values are above 8.3. Thus, the observed values for the variable b* classify the meat as yellow. This may be related to the presence of a higher content of ß-carotene in pasture, because the more ß-carotenes that are present, the greater the influence of these parameters on the meat (Realini et al., 2004).

The slaughter weight had no effect ($p > 0.10$) on shear force (Table 4). The mean shear force was 5.1 kg cm^{-2}. Thus, the meat texture of the three categories of heifers can be classified as tender (Shackelford et al., 1995).

The slaughter weight of the heifers had no effect ($p > 0.10$) on the lipid oxidation of meat (Table 4). The mean values of MDA were 0.19 mg per kg of meat, which is a logical observation since the meat was kept frozen for only three days. Generally, the MDA values of the meat before the ageing period or freezing were below 0.10 mg of MDA per kg of meat. Although the heifers had been completed on pasture, they were supplemented with concentrate of the basic grains and cereals, which has a low vitamin E content (Richardson et al., 2004), making the meat oxidatively less stable. Still, the TBARS values might increase in previously frozen meat due to damage to some cellular structures determining higher oxidation. However, the values observed for all of the meat samples had TBARS values below 2.0 mg per kg of meat MDA, which is considered the maximum in terms of its perception by consumers as rancid (Campo et al., 2006).

Table 4. Colour, texture and lipid oxidation of meat from crossbred heifers with different slaughter weights finished on pasture and supplemented with concentrate.

	Slaughter weights			SEM	p < Values
	Heavy[1]	Medium[2]	Light[3]		
Lightness, L*	37.0	38.4	36.9	0.49	0.39
Redness, a*	12.5	12.1	12.7	0.48	0.89
Yellowness, b*	12.0	12.2	11.8	0.36	0.93
Chrome, C*	17.3	17.2	17.4	0.56	0.99
Tone, H*	43.9	45.1	43.1	0.65	0.49
WBSF, kg cm^{-2}	5.78	4.63	4.94	0.38	0.23
TBARS	0.19	0.21	0.18	0.01	0.62

[1]Slaughter weight = 400 kg, [2]slaughter weight = 360 kg, [3]slaughter weight = 330 kg, SEM = standard error of mean, WBSF = Warner–Bratzler shear force, TBARS = lipid oxidation.

Conclusion

Heifers finished in pasture and supplemented during the last 90 days can be slaughtered at 400, 360 and 330 kg of body weight without change to the carcass characteristics and meat quality, although the heavier heifers (400 kg) presented a better performance.

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