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Evaluation of carcass traits and meat characteristics of Guzerat-crossbred bulls

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ABSTRACT

Our objective was to evaluate carcass and meat characteristics of Guzerat-crossbred bulls finished in feedlot. Carcasses from 18 bulls, randomly selected from a larger group of 36 bulls, consisting of F1 Guzerat × Holstein ("Guzholstein"); F1 Guzerat × Nellore ("Guzonell"); and 1/2 Simmental + 1/4 Guzerat + 1/4 Nellore (Three-Cross; n = 6 each group) were used. Cold carcass weight was greater ($P = 0.01$) for Three-Cross compared with "Guzonell" and "Guzholstein". Three-Cross carcasses had greater ($P < 0.01$) rib-eye-area and 100-kg-adjusted rib-eye-area among groups. *Longissimus lumborum* length did not differ ($P > 0.05$) among groups, but depth was greater ($P < 0.01$) for Three-Cross compared with other groups. "Guzholtein" had lesser ($P = 0.05$) shear force compared with "Guzonell", with Three-Cross being intermediate. We conclude that "Guzholstein" is an adequate option for producers willing to finish this kind of genetic group, as it is comparable or better than *Bos indicus* crosses and *B. indicus* × *Bos taurus* bulls.

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1. Introduction

Beef production in Brazil is becoming more efficient because utilization of technologies that permits reduction of the production cycle. Crossbreeding has been used as a tool to reduce the time-frame of beef production, since crossbred animals are more precocious than purebred *Bos indicus* animals. Crossbred animals are readily available for Brazilian feedlot producers, including animals from dual-purpose enterprises (milk and beef production systems). In addition, crossbreeding programs are becoming more popular among beef producers, either using *B. indicus* (e.g. Nellore and Guzerat) and, or *Bos taurus* (e.g. Simmental) breeds, aiming to explore the benefits of heterosis for meat quality (Gama et al., 2013).

Assessment of parameters correlated with tenderness and meat color such as pH, water-holding capacity and shear force is important because of their relationship with quality and consumer acceptance (Pflanzer & Felício, 2011; Schönfeldt & Strydom, 2011), and when choosing the breed or crossbred animals for certain production system (Melucci et al., 2012; Pacheco et al., 2011). In addition, the evaluation of certain carcass traits is important because it helps assess muscularity and degree of finishing of an animal (Luchiari Filho, 2000). Knowing these characteristics of different Guzerat-crossbred groups is necessary because their greater availability in some regions of Brazil. Accordingly, our objective was to evaluate meat characteristics from three groups of Guzerat-crossbred bulls, finished in feedlot.

2. Material and methods

This study was conducted at the Federal University of Jequitinhonha and Mucuri Valleys ('*Universidade Federal dos Vales do Jequitinhonha e Mucuri*'; UFVJM), Beef Cattle Research and Experiment Sector (Curvelo, Minas Gerais State, Brazil; 44°24′W and 18°49′S), and analyses were performed at the Animal Products Science and Technology Sector (Diamantina, Minas Gerais State, Brazil; 43°34′W and 18°12′S). Bulls utilized in this experiment were cared for by acceptable practices in accordance with the guidelines as outlined in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (Federation of Animal Science Societies, 2010), and the research protocol was

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reviewed and approved by the UFVJM, Committee of Ethics on the Use of Animals.

2.1. Animals, carcasses, and experimental design

Animal management, diet, and experimental conditions of the feedlot where bulls were kept were previously reported by Diniz et al. (2015). Briefly, 36, 23-month-old, beef bulls (F1 Guzerat × Holstein ["Guzholstein"]; F1 Guzerat × Nellore ["Guzonell"]; and 1/2 Simmental + 1/4 Guzerat + 1/4 Nellore [Three-Cross]; n = 12, each group), derived from the same herd and 10 different sires of each breed group, subjected to similar management and kept in same feed supplementation and pasture conditions before entering the feedlot, were allocated into feedlot pens(three bulls in each pen, four pens per group). During 84 days, bulls received sorghum silage and concentrate supplement twice a day with roughage:concentrate ratio of 50:50, DM-basis. Eighteen bulls (six from each group) were transferred to be humanely slaughtered in a State-inspected slaughterhouse, subjected to routine inspection performed by the Minas Gerais State Institute of Agriculture, as outlined in the State Law #11.812/1995. Bulls were randomly selected from all pens (one or two bulls per pen), and slaughtered after 16 h of feed and water withdrawal. The slaughterhouse where bulls were processed was not able to handle in a same day all bulls; thus, we decided to evaluate this limited number of carcasses as we judged to be the minimum number necessary to perform all measurements and analyses without having another variation (day of slaughter).A summary of performance data is depicted in Table 1.

Carcasses were chilled at 4 °C for 24 h. After this period, cold carcass weight (CCW) was determined and 24-h shrink loss was calculated as the difference between hot and cold carcass weights. Subcutaneous fat thickness and rib-eye-area were measured between the 12th and 13th ribs. A mm-graduate precision caliper was used to measure subcutaneous fat thickness, which was obtained 3/4 the length ventrally over the *longissimus lumborum* (LL; Greiner, Rouse, Wilson, Cundiff, & Wheeler, 2003). For rib-eye-area measurement, a tracing paper was utilized; area was estimated using the AutoCad 2007 (Autodesk, Inc., San Rafael, CA) software, and expressed as cm^2. Length of LL was measured as the distance (in cm) beginning at the most lateral point to the most medial point of the surface of the muscle; depth was measured at the same point used to measure subcutaneous fat thickness. Both measurements were performed by using a cm-graduated ruler.

2.2. Meat analyses and measurements

Twenty-four-hour pH, performed after chilling for 24 h, was measured using a pH-meter with an automatic endpoint and buffer recognition as well as temperature compensation, equipped with a penetrating electrode (Model SG2 — ELK Seven Go™, Mettler-Toledo International Inc., Columbus, OH).To calibrate the pH-meter, the apparatus was turned on and after 30 min the electrode was rinsed with distilled water and dabbed with a paper wipe. Then, the electrode was submerged in a 7.0 phosphate buffer at room temperature. Finally, after a new rinse, the electrode was submerged in a 4.0 phosphate buffer.

Water-holding capacity was measured using a modified filter paper press method (Zamorano & Gambaruto, 1997) on samples collected 24 h post-mortem. Briefly, 0.5-g cube samples were placed on a filter paper and pressed between acrylic plates for 5 min, using a 10-kg weight. After pressing, the residual material was removed from the filter paper using a blade and immediately weighed. Weight loss by pressure was calculated as the percentage of the final weight from the sample's initial weight.

Shear force was determined by cooking the LL samples in an oven at 170 °C. The internal temperature was monitored using a 20-gauge copper–constantan thermocouples (Omega Engineering, Stamford, CT) placed in the geometric center of the slice. When the internal temperature reached 35 °C, samples were turned over and allowed to reach 70 °C. After cooking, samples were then removed from the oven and chilled at 4 °C for 24 h. Afterwards, eight cores of 1.27 cm in diameter were removed parallel to the longitudinal orientation of the muscle fibers (American Meat Science Association, 1995), by using a hand-held coring device. Shear force was determined once through the middle and perpendicular to the fiber direction, using a Warner-Bratzler shear device (G-R Manufacturing Company, Manhattan, KS).

Instrumental color analysis was conducted on the surface of the LL after a 30-min air exposition period using the CR-400 hand-held Chroma Meter (Konica Minolta, Inc., Tokyo, Japan) color measurement apparatus; illuminant D65 and geometry 45/0 were employed. Calibration was performed utilizing a white plate supplied by the manufacturer. Surface of the steak was measured for lightness (L^*), red (a^*) and yellow (b^*) intensity in three spots and the average value from these three spots was used.

2.3. Statistical analyses

Analyses for all variables were achieved by ANOVA for a completely randomized design, with three treatments (breed groups), using the GLM procedure of SAS (SAS Institute, Inc., Carry, NC). The model statement contained the effects of genetic group, slaughter weight was fitted as covariate for carcass traits and carcass weight was fitted as covariate for LL characteristics, and pen as the experimental unit. Bulls were randomly selected from each pen and pen was considered as the random term. Least square means were separated for comparison by using the Tukey's Studentized test.

Table 1
A summary of performance data of three Guzerat-crossbred groups previously reported by Diniz et al. (2015).1, 2

Item	Breed group[1]			SEM	*P*-value
	"Guzholstein"	"Guzonell"	Three-Cross		
Final body weight[2] (kg)	498^c	521^b	559^a	16.1	0.01
Average daily gain (kg/day)	1.7^a	1.4^b	1.6^{ab}	0.14	0.04
Gain:feed (g/kg DM consumed)	130	110	120	10.6	0.08
Total body weight gain (kg)	103.1^a	85.8^b	97.5^a	5.44	0.01
Hot carcass weight (kg)	260^c	287^b	307^a	24.8	0.02
Dressing-out percentage (%)	51.6^b	54.2^a	56.0^a	1.83	0.02
Carcass weight gain (kg)	59^b	63^b	80^a	10.40	0.03

Means within a row with different superscript letters differ ($P \leq 0.05$).
[1] Thirty-six, 23-month-old, beef bulls from 3 breed groups (Guzerat; F1 Guzerat × Holstein ('Guzholstein'); F1 Guzerat × Nellore ('Guzonell'); and 1/2 Simmental + 1/4 Guzerat + 1/4 Nellore (Three-Cross); n = 12, each group) derived from the same herd and different sires of each breed group, subjected to similar prior management, were kept in an experimental feedlot for 84 days, as previously described by Diniz et al. (2015).
[2] Body weight was measured after 16 h of feed and water withdrawal at the end of the 84-day feedlot period.

3. Results

3.1. Carcass data

Cold carcass weight was greater ($P < 0.01$) for Three-Cross compared with "Guzonell" and "Guzholstein", which had lesser CCW than "Guzonell" bulls (Table 2). Three-Cross carcasses had greater ($P < 0.01$) rib-eye-area among groups, with "Guzonell" and "Guzholstein" bulls having similar values. Similarly, 100-kg-adjusted rib-eye-area was greater ($P = 0.05$) for Three-Cross than "Guzonell" and "Guzholstein", with both groups not differing. The LL length did not differ ($P = 0.33$) among groups. However, muscle depth was greater ($P = 0.03$) for Three-Cross compared with another groups. Length and depth ratio was 1.86, 2.07, and 2.13 for Three-Cross, "Guzholstein" and "Guzonell", respectively. Subcutaneous fat thickness and 24-h shrink loss did not differ ($P \geq 0.23$) among groups.

3.2. Meat measurements

Twenty-four-hour pH, water-holding capacity, L^*,a^*, and b^* intensity did not differ ($P > 0.35$) among groups (Table 3).However, "Guzonell" and "Three-Cross" bulls had greater ($P = 0.06$) shear force compared with "Guzholstein".

4. Discussion

Differences in CCW among groups are expected because of differences in body weight at slaughter, as depicted in Table 1. Our results were greater than values reported by Vaz et al. (2002), who evaluated 3/4 Charolais × 1/4 Nellore and 3/4 Nellore × 1/4 Charolais bulls with similar age.

B. taurus animals have a greater growth rate and, consequently, tend to have greater rib-eye-area than *B. indicus* animals (Lopes et al., 2012). Three-Cross and "Guzholstein" bulls have 50% of *B. taurus* genetics on their breed composition, which come from Simmental and Holstein breeds, respectively. On the other hand, "Guzonell" animals have in their composition 100% of *B. indicus* genetics. The Simmental breed may have contributed to greater heterosis in Three-Cross bulls and hence favored for some carcass traits, such as greater rib-eye-area, compared with other groups. "Guzholstein" bulls, because they contain a breed selected for milk production in their composition (Holstein), have lesser potential for muscularity. Fernandes et al. (2005) reported that F1 Holstein ×*B. indicus* animals had a greater composition of internal organs and visceral fat on shrunk body weight gain compared with *B. indicus* animals. Greater rib-eye-areas of *B. taurus* crosses were also reported by Lopes et al. (2008), who performed a meta-analysis of 36 studies to compare different genetic groups. Elzo, Johnson, Wasdin, and Driver (2012) also reported greater rib-eye-areas for *B. taurus* crosses up to 50% of *B. indicus* influence.

Rib-eye-area is affected by body weight, and adjustment to an equivalent of 100 kg of carcass weight is a better approach in comparing groups (Leme et al., 2000). According to Luchiari Filho (2000), the rib-eye-area adjusted to 100 kg should be at least 29.0 cm^2. In the current study, only Three-Cross bulls had greater value than the benchmark. "Guzonell" and "Guzholtein" bulls had lesser values, also reported by other authors who evaluated *B. indicus* crossbred animals (Ezequiel, Galati, Mendes, & Faturi, 2006; Lage et al., 2012).

Brazilian slaughterhouse industry requires 3 mm of subcutaneous fat thickness as a standard for carcasses. According to Luchiari Filho (2000), subcutaneous fat thickness is important to carcass shield against cold shortening during chilling, and 2 mm is the minimum value acceptable for maintaining meat quality. Our values were around these benchmarks. Similarly, Climaco et al. (2006) and Yüksel et al. (2012) reported values lesser than 3 mm for bulls finished in pastures. For bulls finished in feedlot, Miotto et al. (2012) and Rezende et al. (2012) also reported values lesser than 3 mm when evaluating *B. taurus* × *B. indicus* animals.

Shrink loss was affected by subcutaneous fat thickness. According to Müller (1987), this trait is influenced by fat content in the carcass or subcutaneous fat thickness, which works as an insulator, avoiding losses by dehydration. Therefore, carcasses with greater fat content have less losses during chilling process. Lesser losses represent better cold carcass yield, which is important to the slaughterhouses. Our values were greater than previous reports (Pacheco et al., 2013; Zorzi et al., 2013). However, these authors reported values greater than 3 mm for subcutaneous fat thickness.

Normal values for 24-h pH range from 5.4 to 5.6 (Abularach, Rocha, & Felício, 1998), but Luchiari Filho (2000) considered 5.6 and 5.8 the desirable range for fresh meat. Water-holding capacity is reduced by the post-mortem decline in pH because anaerobic fermentation of glycogen and lactic acid formation (Duarte et al., 2011; Fernandes et al., 2009). According to Fernandes et al. (2009), at pH 5.5, a greater spacing between protein filaments due to increased repulsion is observed, because of prevalence of negative charges, resulting in greater water retention and less shear force. However, at muscle isoelectric point (pH 5.2 to 5.3), there is an equilibrium between positive and negative charges with lesser spacing between fibers and therefore less water-holding capacity (Fernandes et al., 2009). On the other hand, pH values above 5.8 is related with less muscle glycogen reserves, associated with dark colored meat and less shelf life (Immonen, Ruusunen, & Puolanne, 2000). The average pH value observed in this study lies within the desirable pH range, which resulted in similar values for shear force and color parameters.

Lack of genetic group effect on water-holding capacity is probably because of similar muscle pH among groups. Greater water-holding

Table 2
Carcass traits and *longissimus lumborum* characteristics of three Guzerat-crossbred groups.1, 2

Item	Breed group[1]			SEM	*P*-value
	"Guzholstein"	"Guzonell"	Three-Cross		
Cold carcass weight (kg)	254[c]	278[b]	294[a]	6.3	<0.01
Rib-eye-area (cm^2)	62.7[b]	74.4[b]	87.0[a]	3.46	<0.01
100-kg-adjusted rib-eye-area (cm^2)	24.7[b]	26.8[b]	29.6[a]	1.33	0.05
Length[1] (cm)	13.5	14.5	14.7	0.36	0.33
Depth[2] (cm)	6.5[b]	6.8[b]	7.9[a]	0.22	0.03
Subcutaneous fat thickness (mm)	1.9	2.6	1.9	0.17	0.21
Shrink loss (%)	3.0	2.9	3.5	0.54	0.23

Means within a row with different superscript letters differ ($P \leq 0.05$).
[1] Eighteen, 23-month-old, beef bulls from 3 breed groups (n = 6, each group) were evaluated: (1) F1 Guzerat × Holstein ("Guzholstein"); (2) F1 Guzerat × Nellore ("Guzonell"); and (3) 1/2 Simmental + 1/4 Guzerat + 1/4 Nellore (Three-Cross).
[2] Length and depth were measured on the *longissimus lumborum*.

Table 3
Characteristics of *longissimus lumborum* from three Guzerat-crossbreed groups.1, 2, 3, 4

Item	Breed group[1]			SEM	*P*-value
	"Guzholstein"	"Guzonell"	Three-Cross		
24-h pH	5.6	5.6	5.5	0.04	0.53
Water-holding capacity (%)	32.6	35.4	32.9	0.88	0.35
Shear force (N)	43.1[b]	50.9[a]	50.1[a]	1.56	0.06
L^*[2]	41.7	41.7	41.6	0.03	0.92
a^*[3]	14.2	14.2	14.1	0.08	0.91
b^*[4]	1.3	1.3	1.4	0.02	0.93

Means within a row with different superscript letters differ ($P \leq 0.05$).
[1] Eighteen, 23-month-old, beef bulls from 3 breed groups (n = 6, each group) were evaluated: (1) F1 Guzerat × Holstein ("Guzholstein"); (2) F1 Guzerat × Nellore ("Guzonell"); and (3) 1/2 Simmental + 1/4 Guzerat + 1/4 Nellore (Three-Cross).
[2] Lightness.
[3] Red intensity.
[4] Yellow intensity.

capacity implies in less loss of nutritive value through released exudate and, consequently, more succulent and tender meat (Zeola, Souza, Souza, Silva Sobrinho, & Barbosa, 2007). Water-holding capacity is related with age, carcass fat content, and marbling, in which meat from younger animals and with greater fat content tend to lose less water during cooking compared with meat from older animals or with less fat content (Bianchini et al., 2007; Pacheco et al., 2011). Furthermore, water-holding capacity can also be influenced by the amount of collagen because, when heated, it compresses muscle fibers by increasing water loss (Lawrie & Ledward, 2006). In our knowledge, there is no benchmark value for water-holding capacity. In the current study, bulls had similar age and, even "Guzonell" bulls having a numerically greater subcutaneous fat thickness value, water-holding capacity was not affected by genetic groups.

Shear force is a measurement that indicates tenderness, mechanically assessed through force necessary to sever the muscle fibers. A shear force value of 6 kg is considered as the margin between tender and tough (Shackelford, Wheeler, & Koohmaraie, 1997). All genetic groups had lesser shear force values than 6 kg (~ 58.8 N), demonstrating that all groups yielded tender meat, regardless of *B. indicus* and or *B. taurus* participation in the genetic groups evaluated in this study. An interesting finding of this study was that bulls from dual-purpose production systems produced meat considered very tender, according to the scale proposed by Bickerstaffe, Bekhit, Robertson, Roberts, and Geesink (2001). Despite the fact that pH values were above the isoelectric point and below 5.8 and not differing among groups, shear force was less for "Guzholstein" bulls probably because of the less calpain calpastatin ratio. Although the calpain–calpastatin system was not evaluated in the current study, it is known that animals with greater *B. taurus* participation have lesser calpastatin (Pringle, Williams, Lamb, Johnson, & West, 1997), contributing to a greater tenderness. In addition, collagen content of meat from the "Guzonell" and Three-Cross groups may have affected shear force values, since animals with *B. indicus* breeding have greater gene expression for *lysyl oxidase* and *cystatin C* (which are related with collagen content), and greater shear force (Gonzalez et al., 2014).

Color of meat is affected by the amount of myoglobin and extent of oxidation when exposed to oxygen (Lawrie & Ledward, 2006). Generally, consumers prefer a bright cherry-red meat. Lack of genetic group effect on color characteristics probably can be because similar values observed for pH among groups, correct management during slaughtering procedures (ante- and post-mortem) in addition to the proper process in converting muscle to meat.

In summary, although evaluating a reduced number of carcasses, we observed that Three-Cross bulls had better carcass traits than "Guzholstein" and "Guzonell". However, all genetic groups had low value for subcutaneous fat thickness. "Guzholstein" bulls had tenderer meat compared with other groups. We conclude that "Guzholstein" could be an option for producers willing to finish this kind of breed group, as it is comparable or better than *B. indicus* cross and *B. indicus* × *B. taurus* bulls.

Conflict of interest

The authors declare no conflict of interest.

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References

Abularach, M. L., Rocha, C. E., & Felício, P. E. (1998). Características de qualidade do contra-filé (m. *L. dorsi*) de touros jovens da raça Nelore. *Ciência e Tecnologia de Alimentos*, *18*, 205–210.

American Meat Science Association (1995). *Research guidelines for cookery, sensory evaluation and instrumental tenderness measurements of fresh meat.* Chicago: American Meat Science Association.

Bianchini, W., Silveira, A. C., Jorge, A. M., Arrigoni, M. B., Martins, C. L., Rodrigues, E., ... Andrighetto, C. (2007). Efeito do grupo genético sobre as características de carcaça e maciez da carne fresca e maturada de bovinos superprecoces. *Revista Brasileira de Zootecnia*, *36*, 2109–2117.

Bickerstaffe, R., Bekhit, A. E. D., Robertson, L. J., Roberts, N., & Geesink, G. H. (2001). Impact of introducing specifications on the tenderness of retail meat. *Meat Science*, *59*, 303–315.

Climaco, S. M., Ribeiro, E. L. A., Rocha, M. A., Mizubuti, I. Y., Silva, L. D. F., Noro, L. Y., & Turini, T. (2006). Características de carcaça e qualidade de carne de bovinos inteiros ou castrados da raça Nelore, suplementados ou não durante o primeiro inverno. *Ciência Rural*, *36*, 1867–1872.

Duarte, M. S., Paulino, P. V. R., Valadares Filho, S. C., Paulino, M. F., Detmann, E., Zervoudakis, J. T., ... Serão, N. V. L. (2011). Performance and meat quality traits of beef heifers fed with two levels of concentrate and ruminally undegradable protein. *Tropical Animal Health and Production*, *43*, 877–886.

Diniz, F. B., Villela, S. D. J., Mourthé, M. H. F., Paulino, P. V. R., Pires, A. V., Sousa, R. C., ... Martins, P. G. M. A. (2015). Performance of beef Guzerat and Guzerat-cross bulls during the feedlot, and carcass traits of Guzerat-cross groups. *Animal Production Science*, *55*, 1303–1309.

Elzo, M. A., Johnson, D. D., Wasdin, J. G., & Driver, J. D. (2012). Carcass and meat palatability breed differences and heterosis effects in an Angus–Brahman multibreed population. *Meat Science*, *90*, 87–92.

Ezequiel, J. M. B., Galati, R. L., Mendes, A. R., & Faturi, C. (2006). Desempenho e características de carcaça de bovinos Nelore em confinamento alimentados com bagaço de cana-de-açúcar e diferentes fontes energéticas. *Revista Brasileira de Zootecnia*, *35*, 2050–2057.

Federation of Animal Science Societies (2010). *Guide for the care and use of agricultural animals in agricultural research and teaching* (3rd ed.). Champaign: Federation of Animal Science Societies.

Fernandes, A. R. M., Sampaio, A. A. M., Henrique, W., Oliveira, E. A., Oliveira, R. V., & Leonel, F. R. (2009). Composição em ácidos graxos e qualidade da carne de tourinhos Nelore e Canchin alimentados com dietas à base de cana-de-açúcar e dois níveis de concentrado. *Revista Brasileirade Zootecnia*, *38*, 328–337.

Fernandes, H. J., Paulino, M. F., Martins, R. G. R., Valadares Filho, S. C., Torres, R. A., Paiva, L. M., & Ribeiro, V. A. (2005). Crescimento de componentes corporais de três grupos genéticos nas fases de recria e terminação. *Revista Brasileira de Zootecnia*, *34*, 288–296.

Gama, L. T., Bressan, M. C., Rodrigues, E. C., Rossato, L. V., Moreira, O. C., Alves, S. P., & Bessa, R. J. B. (2013). Heterosis for meat quality and fatty acid profiles in crosses among *Bos indicus* and *Bos taurus* finished on pasture or grain. *Meat Science*, *93*, 98–104.

Gonzalez, J. M., Johnson, D. D., Elzo, M. A., White, M. C., Stelzleni, A. M., & Johnson, S. E. (2014). Effect of Brahman genetic influence on collagen enzymatic crosslinking gene expression and meat tenderness. *Animal Biotechnology*, *25*, 165–178.

Greiner, S. P., Rouse, G. H., Wilson, D. E., Cundiff, L. V., & Wheeler, T. L. (2003). The relationship between ultrasound measurements and carcass fat thickness and longissimus muscle area in beef cattle. *Journal of Animal Science*, *81*, 676–682.

Immonen, K., Ruusunen, M., & Puolanne, E. (2000). Some effects of residual glycogen concentration on the physical and sensory quality of normal pH beef. *Meat Science*, *55*, 33–38.

Lage, I. N. K., Paulino, P. V. R., Pires, C. V., Villela, S. D. J., Duarte, M. S., Valadares Filho, S. C., ... Teixeira, C. R. V. (2012). Intake, digestibility, performance, and carcass traits of beef cattle of different gender. *Tropical Animal Health and Production*, *44*, 361–367.

Lawrie, R. A., & Ledward, D. (2006). *Lawrie's Meat Science* (7th ed.). Boca Raton, FL: CRC Press LLC.

Leme,P.R.,Boin, C., Margarido, R.C.C., Tedeschi, L.O., Hausknecht, J.C.O.V., Alleoni, G.F., & Luchiari Filho, A. (2000).Desempenho em confinamento e características de carcaça de bovinos machos de diferentes cruzamentos abatidos em três faixas de peso.Revista Brasileirade Zootecnia,29,2374–2353.

Lopes, J. S., Rorato, P. R. N., Weber, T., Rodrigues, E. D., Comin, J. G., & Dornelles, M. A. (2008). Metanálise para características de carcaça de bovinos de diferentes grupos genéticos. *Ciência Rural*, *38*, 2278–2284.

Lopes, L. S., Ladeira, M. M., MachadoNeto, O. R., Paulino, P. V. R., Chizzotti, M. L., Ramos, E. M., & Oliveira, D. M. (2012). Características de carcaça e cortes comerciais de tourinhos Red Norte e Nelore terminados em confinamento. *Revista Brasileira de Zootecnia*, *41*, 970–977.

Luchiari Filho, A. (2000). *Pecuária da carne bovina.* São Paulo, Brazil: R.Vieira Gráfica e Editora.

Melucci, L. M., Panarace, M., Feula, P., Villarreal, E. L., Grigioni, G., Carduza, F., ... Miquel, M. C. (2012). Genetic and management factors affecting beef quality in grazing Hereford steers. *Meat Science*, *92*, 768–774.

Miotto, F. R. C., Restle, J., Neiva, J. N. M., Resende, P. L. P., Lage, M. E., Prado, C. S., ... Araújo, V. L. (2012). Farelo do mesocarpo de babaçu (*Orbygnia*sp.) na terminação de bovinos, composição física da carcaça e qualidade da carne. *Ciência Rural*, *42*, 1271–1277.

Müller, L. (1987). *Normas para avaliação de carcaças e concurso de carcaças de novilhos* (2nd ed.). Santa Maria, Brazil: UFSM.

Pacheco, P. S., Restle, J., Alves Filho, D. C., Brondani, I. L., Pascoal, L. L., Kuss, F., ... Neiva, J. N. M. (2011). Carcass physical composition and meat quality of Charolais cattle of different categories. *Revista Brasileira de Zootecnia*, *40*, 2597–2605.

Pacheco, P. S., Restle, J., Missio, R. L., Menezes, L. F. G., Rosa, J. R. P., Kuss, F., Alves Filho, D. C., Neiva, J. N. M., & Donicht, P. A. M. M. (2013). Características da carcaça e do corpo vazio de bovinos Charolês de diferentes categorias abatidos com similar grau de acabamento. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *65*, 281–288.

Pflanzer, S. B., & Felício, P. E. (2011). Moisture and fat content, marbling level and color of boneless rib cut from Nellore steers varying in maturity and fatness. *Meat Science*, *87*, 7–11.

Pringle, T. D., Williams, S. E., Lamb, B. S., Johnson, D. D., & West, R. L. (1997). Carcass characteristics, the calpain proteinase system, and aged tenderness of Angus and Brahman crossbred steers. *Journal of Animal Science*, *75*, 2955–2961.

Rezende, P. L. P., Restle, J., Fernandes, J. J. R., FreitasNeto, M. D., Prado, C. S., & Pereira, M. L. R. (2012). Carcass and meat characteristics of crossbred steers submitted to different nutritional strategies at growing and finishing phases. *Ciência Rural*, *42*, 875–881.

Schönfeldt, H. C., & Strydom, P. E. (2011). Effect of age and cut on tenderness of South African beef. *Meat Science*, *87*, 206–218.

Shackelford, S. D., Wheeler, T. L., & Koohmaraie, M. (1997). Tenderness classification of beef, I. Evaluation of beef longissimus shear force at 1 or 2 days postmortem as a predictor of aged beef tenderness. *Journal of Animal Science*, *75*, 2417–2422.

Vaz, F. N., Restle, J., AlvesFilho, D. C., Brondani, I. L., Pascoal, L. L., Vaz, R. Z., & Peixoto, L. A. O. (2002). Características de carcaça e da carne de novilhos filhos de vacas 1/2 Nelore 1/2 Charolês e 1/2 Charolês 1/2 Nelore acasaladas com touros Charolês ou Nelore. *Revista Brasileira de Zootecnia*, *31*, 1734–1743.

Yüksel, S., Yanar, M., Aksu, M. I., Kopuzlu, S., Kaban, G., Sezgin, E., & Oz, F. (2012). Effects of different finishing systems on carcass traits, fatty acid composition, and beef quality characteristics of young Eastern Anatolian Red bulls. *Tropical Animal Health and Production*, *44*, 1521–1528.

Zamorano, J. M., & Gambaruto, M. (1997). Contribution to improving the meat water holding capacity test by the filter paper press method. A comparison of three methods for measuring areas. *Meat Science*, *46*, 129–137.

Zeola, N. M. B. L., Souza, P. A., Souza, H. B. A., Silva Sobrinho, A. G., & Barbosa, J. C. (2007). Cor, capacidade de retenção de água e maciez da carne de cordeiro maturada e injetada com cloreto de cálcio. *Arquivo Brasileiro de Medicina Veterinária e Zootecnia*, *59*, 1058–1066.

Zorzi, K., Bonilha, S. F., Queiroz, A. C., Branco, R. H., Sobrinho, T. L., & Duarte, M. S. (2013). Meat quality of young Nellore bulls with low and high residual feed intake. *Meat Science*, *93*, 593–599.