

# CHEMICAL AND SENSORY MEAT CHARACTERISTICS OF NELLORE CATTLE (*Bos indicus*) FINISHED WITH DIFFERENT LEVELS OF BACKFAT THICKNESS IN THE LONGISSIMUS THORACIS MUSCLE<sup>1</sup>

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**ABSTRACT:** The objective of this study was to evaluate the effect of backfat thickness (BFT) on the meat quality of feedlot-finished Nellore bulls (*Bos indicus*). Seventy-two animals were feedlot finished for about 100 days. For this study, 24 animals were sampled according to BFT in the longissimus thoracis muscle after slaughter: 12 animals with BFT up to 3.0 mm (class BFT-3) and 12 animals with BFT > 6.0 mm (class BFT-6). Chemical (myofibrillar fragmentation index, intramuscular fat content, and unsaturated and saturated fatty acids) and physical (cold carcass weight, rib eye area, and marbling score) characteristics of the meat were evaluated. Additionally, shear force and sensory characteristics (aroma, flavor, tenderness, chewiness, and juiciness) were analyzed. Marbling score and intramuscular fat content were considered low for the two BFT classes. The mean values of the characteristics studied did not differ ( $P>0.05$ ) between BFT classes, except for fatty acids, with the observation of higher unsaturated fatty acid levels in the BFT-6 class. There was no difference ( $P>0.05$ ) in sensory characteristics between BFT classes. The most consistent relationship was observed between the myofibrillar fragmentation index and tenderness, measured as shear force, in animals with greater BFT (BFT-6 class) compared to animals with lower BFT (BFT-3 class), suggesting possible tenderness problems in animals with a leaner carcass. The observation of a higher concentration of unsaturated fatty acids in animals with greater BFT suggests an increase in the sensory perception of meat, especially flavor.

**Keywords:** sensory analysis, fat composition, muscle growth, tenderness.

## CARACTERÍSTICAS QUÍMICAS E SENSORIAIS DA CARNE DE BOVINOS NELORE (*Bos indicus*) TERMINADOS COM DIFERENTES ESPESSURAS DE GORDURA SUBCUTÂNEA NO LONGISSIMUS THORACIS

**RESUMO:** O objetivo deste estudo foi avaliar o efeito da espessura de gordura subcutânea (EGS) na qualidade da carne de bovinos machos Nelore (*Bos indicus*), inteiros, terminados em confinamento. Setenta e dois animais foram terminados em confinamento por cerca de 100 dias. Para o presente estudo, 24 animais foram amostrados de acordo com a EGS obtida no longissimus thoracis, após o abate: 12 animais com EGS até 3,0 mm (classe EGS-3) e 12 animais com EGS maior que 6,0 mm (classe EGS-6). Foram avaliadas características químicas da carne (índice de fragmentação miofibrilar, conteúdo de lipídeos intramusculares e ácidos graxos insaturados e saturados), e características físicas da carcaça (peso da carcaça resfriada, área de olho de lombo e escore de marmorização). Adicionalmente, foram avaliadas em amostras maturadas por 21 dias, a força de cisalhamento

e características sensoriais (aroma, sabor, maciez, mastigabilidade e suculência). Os valores de escore de marmorização e de conteúdo de lipídeos intramusculares foram considerados baixos para ambas as classes de EGS. As médias das características avaliadas não diferiram ( $P>0,05$ ) entre as classes de EGS, com exceção dos ácidos graxos, que foi superior para o insaturado na classe EGS-6. As características sensoriais não diferiram ( $P>0,05$ ) entre as classes de EGS. Foi verificada relação mais consistente entre índice de fragmentação miofibrilar e maciez, medida pela força de cisalhamento, em animais com maior EGS (classe EGS-6), comparativamente a animais com menor EGS (classe EGS-3), o que sugere possível problema de maciez em animais de carcaça mais magra. A observação de maior concentração de ácidos graxos insaturados em animais com maior EGS sugere aumento da percepção sensorial da carne, especialmente do sabor.

Palavras-chave: análise sensorial, composição lipídica, crescimento muscular, maciez.

## INTRODUCTION

Brazil is the second largest producer of meat in the world, amounting to 9.3 million metric tons of carcass (USDA, 2013). Current consumption patterns demand high-quality foods. Within this context, beef is below the quality desired by the consumer due to the lack of standardization of the products offered (VAZ *et al.*, 2007). The most valued qualitative attributes are tenderness (SHACKELFORD *et al.*, 2001) and flavor (UMBERGER *et al.*, 2002).

The influence of animal feeding on meat tenderness has been suggested to be related to backfat thickness (BFT) and intramuscular fat content (marbling). Studies have shown that carcasses with adequate fat coverage and good marbling degree tend to present more tender meat evaluated by laboratory techniques or taste panels (KILLINGER *et al.*, 2004). Increased BFT guarantees protection of the carcass (thermal insulation) during storage in the cold chamber, reducing the impact of rapid cooling by preventing the shortening of muscle fibers which compromises meat tenderness (TAIT *et al.*, 2005).

In Nellore cattle, the percentage of fat evaluated in longissimus thoracis muscle varies according to the degree of maturity of the animal, usually reaching lower levels of 2 to 3% (DUARTE *et al.*, 2011; OLIVEIRA *et al.*, 2012) than those observed in taurine animals. However, levels higher than 4% have been reported (PFLANZER and FELÍCIO, 2011). When choosing products, consumers observe characteristics such as meat color, cut size, and especially the amount of intramuscular and subcutaneous fat (SILVEIRA *et al.*, 2010) to classify the quality of the product.

The objective of the present study was to evaluate the direct effects of variations in BFT, carcass finishing, on the main meat quality traits (with emphasis on tenderness) of feedlot-finished Nellore bulls (*Bos indicus*).

## MATERIAL AND METHODS

The field experiment was conducted in experimental feedlot facilities, Botucatu, SP, Brazil. Seventy-two Nellore bulls (32 months and 360 kg of initial age and weight) were feedlot-finished for about 100 days. For the present study, 24 animals were sampled according to BFT after slaughter: 12 animals with BFT of up to 3.0 mm (BFT-3 class) and 12 animals with BFT higher than 6.0 mm (BFT-6 class).

After adaptation to the feedlot facility for 15 days, the animals received a diet for maximum daily weight gain consisting of approximately 15% crude protein and 78% total digestible nutrients. The diet was offered twice a day (7:00 and 16:00 h) at a ratio of 82% concentrate and 18% roughage. The concentrate ration contained coarsely ground corn (60%), soybean hulls (28%), soybean meal (7%), and ionophore (5%) and urea (0.25%) as additives. The roughage fraction consisted of sugarcane bagasse and hay at a proportion of 1:1, corresponding to 18% of the total diet.

After the feedlot period, the animals were slaughtered (535 kg of final weight) at a commercial slaughterhouse according to guidelines of humane slaughter (LUDTKE *et al.*, 2012) and the carcasses were cooled for 24 h at  $-4^{\circ}\text{C}$ . After cooling, three samples/animal with a thickness of one inch (2.54 cm) of the left half-carcass between the 9<sup>th</sup> and 13<sup>th</sup> ribs longissimus thoracis (LT) muscle were removed. Two of these samples were vacuum packed in suitable plastic bags and stored at a mean temperature of  $1^{\circ}\text{C}$  for 21 days (504 h) for determination of meat tenderness (shear force) and sensory analysis. The third sample was identified, packed in a plastic bag, and frozen in a freezer at  $20^{\circ}\text{C}$  for subsequent chemical analysis.

Backfat thickness was measured with a

millimeter caliper and rib eye area (REA) was determined by square points in cm<sup>2</sup>. The marbling score was determined by visual grading using an adapted scale (USDA - Quality and Yield Grade, 2000). Shear force was analyzed using the method proposed by WHEELER *et al.* (1997), in which 2.54 cm samples removed between the 12<sup>th</sup> and 13<sup>th</sup> rib were cooked to an internal temperature of 71°C (measured with thermocouples) in an electrical oven previously heated to 180°C. The samples were then cooled for 24 h to reach an internal temperature of 5 °C. Six 1.27 cm cores were removed from the edible portion of the sample for shear force determination using a mechanical Warner-Bratzler shear machine with a capacity of 25 kg and cutting speed of 20 cm/minute. Shear force was analyzed as a mean of the six measurements.

Sensory analysis was performed by a properly selected and trained four-member team for elaboration of a panel of sensory quality characteristics according to the method proposed by CROSS *et al.* (1978). Aroma, flavor, texture, juiciness, chewiness, color, and appearance of the samples were evaluated on a 9-point scale and by descriptive analysis according to the protocols of the American Meat Science Association (1978).

The myofibrillar fragmentation index (MFI) was determined as described by CULLER *et al.* (1978). The MFI was calculated by obtaining absorbance in a spectrophotometer at 540 nm multiplied by 200 to obtain the values of myofibrillar fragmentation. The degree of saturation of fatty acids was determined using the iodine value (INSTITUTO ADOLFO LUTZ, 2008). The intramuscular fat (IMF) content of LT muscle was determined based on the percentage in samples free of subcutaneous fat and connective tissue extracted with chloroform-methanol (BLIGH and DYER, 1959).

A model of simple variance analysis was adopted, which only included the effect of BFT classes (BFT-3 and BFT-6) and error. GLM procedure of SAS (SAS Inst., Inc., Cary, NC) was used for analysis. Adjusted mean values were compared by the Tukey-Kramer test at a level of significance of 5%. CORR procedure was used to estimate simple correlations between the meat quality traits. A regression of MFI on shear force, within BFT classes, was performed using REG procedure.

## RESULTS AND DISCUSSION

Table 1 shows the results of physical analysis of the LT muscle samples. No differences ( $P>0.05$ ) in

the carcass and meat traits were observed between the BFT classes. The carcasses produced, with a mean weight of 286.32 kg, were within the weight range considered to be adequate for the Brazilian beef industry to permit high profitability of beef cuts and easy commercialization of the products (SILVEIRA *et al.*, 2010).

**Table 1. Mean and standard error of cold carcass weight, backfat thickness, rib eye area, marbling score, and shear force of animals, according to backfat thickness class**

Trait	BFT class <sup>1</sup>	
	BFT-3	BFT-6
Cold carcass weight (kg)	289.96 ± 6.77	282.68 ± 6.77
Backfat thickness (mm)	2.53 ± 0.18 b	6.19 ± 0.18 a
Rib eye area (cm <sup>2</sup> )	65.08 ± 1.95	68.08 ± 1.95
Marbling score	3.39 ± 0.12	3.50 ± 0.12
Shear force (kg)	3.31 ± 0.27	2.74 ± 0.15

<sup>1</sup>BFT-3: backfat thickness of less than 3.0 mm; BFT-6: backfat thickness of higher than 6.0 mm.

Means followed by different letters in the line are different ( $P<0.05$ ).

Rib eye area can be used as an indicator trait of carcass composition since it is associated with musculature and yield of high-value cuts. Additionally, this measure is positively correlated with the edible portion of the carcass (RIBEIRO *et al.*, 2004; PFLANZER and FELÍCIO, 2009). According to CRUZ *et al.* (2004), REA increases with increasing weight of the animals, with values higher than 30 cm<sup>2</sup>/100 kg carcass being considered an adequate conformation. RUBIANO *et al.* (2009), studying Nellore cattle slaughtered at 24 months of age, related an REA of 67.18 cm<sup>2</sup>. This value is similar to the results of the present study in which no significant difference ( $P>0.05$ ) was observed between BFT classes. Analyzing data from 11,786 animals, ZUIN *et al.* (2012) obtained a mean ultrasound-measured REA of 52.93 cm<sup>2</sup> (range: 21.86 to 114.1 cm<sup>2</sup>). There were no significant differences ( $P>0.05$ ) in the marbling degree of the meat samples evaluated using a subjective score. The scores ranged from the visual absence of fat to traces of marbling (slight). RUBIANO *et al.* (2009) also observed practically no or little traces of marbling in Nellore cattle with BFT > 4 mm. The small differences in marbling scores can be explained by the fact that the Nellore breed develops very little muscle tissue compared to subcutaneous fat tissue and by its low ability to deposit intramuscular fat until 24 months of age, classifying it as a lean breed (CHARDULO *et al.*, 2014).

No significant differences ( $P>0.05$ ) in shear force were observed between the two classes (BFT-3 and BFT-6) (Table 1). In the present study, all meat samples were aged for 21 days at a mean temperature of 1 °C. The shear force values were within the acceptable range of beef tenderness, which is about 4.6 kg according to SHACKELFORD *et al.* (1991).

Studying 15 different European breeds, CHRISTENSEN *et al.* (2011) reported shear force values of LT muscle samples ranging from 3.07 kg (Avileña-Negra Ibérica) to 4.72 kg (Simmental) after 10 days of aging. The process of aging directly affects shear force, which is characterized by a decrease in the values measured in kg (FRENCH *et al.*, 2001; MONSÓN *et al.*, 2004), and is an efficient alternative to solve differences in tenderness, generating a homogenous product for consumers and increasing its market value (MONSÓN *et al.*, 2004; STENSTRÖM *et al.*, 2014).

The two BFT classes did not differ significantly ( $P>0.05$ ) in terms of IMF percentages as shown in Table 2. SCHOONMAKER *et al.* (2002) reported an IMF percentage of 0.9% in LT muscle of young animals. However, RUBIANO *et al.* (2009), studying 24-month-old Nellore animals with a BFT of 6.9 mm, observed IMF percentages close to 1.6%. Considering that consumers attribute increasing importance to the nutritional qualities of meat, a reduction in IMF can be potentially beneficial for human health (HOCQUETTE *et al.*, 2012). Studying Charolais cattle aged 15 to 19 months, these authors observed mean IMF percentages of 1.35% and 1.95% in rectus abdominis and semitendinosus muscles, respectively. Furthermore, in many countries meat is basically produced from the carcasses of young bulls with little marbling (STENSTRÖM *et al.*, 2014).

Significant differences ( $P<0.01$ ) were observed in the percentage of saturated (SFA) and unsaturated fatty acids (UFA) between the two BFT classes (Table 2). The increase in carcass fat coverage, characterized by an increase in BFT, resulted in a significant increase in the concentration of SFA despite the similar marbling degree in the two groups ( $P>0.05$ ) (Table 1).

Beef fat contains a high proportion of SFA in relation to total fatty acids as a result of the process of biohydrogenation of unsaturated fatty acids by rumen bacteria (HOCQUETTE *et al.*, 2012). The proportions of SFA observed in the present study were considered to be high for animals of this age and the amount of subcutaneous fat. However, HOCQUETTE *et al.* (2012) stated that SFA in a 100 g steak cut from LT muscle of young bulls account for 1 to

**Table 2. Mean and standard error of intramuscular fat content, myofibrillar fragmentation index and unsaturated and saturated fatty acids in meat samples of animals, according to backfat thickness class**

Trait	BFT class <sup>1</sup>	
	BFT-3	BFT-6
Intramuscular fat content (%)	0.94 ± 0.10	0.70 ± 0.10
Myofibrillar fragmentation index	67.42 ± 5.30	79.05 ± 5.30
Unsaturated fatty acids	39.29 ± 3.19 b	64.14 ± 3.19 a
Saturated fatty acids	60.70 ± 3.19 a	35.85 ± 3.19 b

<sup>1</sup>BFT-3: backfat thickness of less than 3.0 mm; BFT-6: backfat thickness of higher than 6.0 mm.

Means followed by different letters in the line are different ( $P<0.05$ ).

5% of the recommended maximum consumption of these fatty acids for humans. Analysis of fatty acid concentration by the iodine value was performed in all lipid fractions of the sample which contained subcutaneous and intramuscular fat. This approach did not permit to identify which adipose tissue would be responsible for this increase in SFA concentration in meat.

Although there was no difference ( $P>0.05$ ) in mean MFI between the two groups (Table 2), a direct association was observed between MFI and shear force, with animals with higher BFT exhibiting lower shear force values and higher MFI. The MFI was higher than 60 in the BFT classes studied. According to CULLER *et al.* (1978), this finding might be associated with meat samples that exhibit lower shear force values and are therefore more tender.

Sensory analysis revealed no significant differences ( $P>0.05$ ) in the characteristics analyzed (Table 3). In a study involving *Bos taurus* and crossbred *Bos indicus* x *Bos taurus* animals, OKA *et al.* (2002) found a negative association of sensory panel score with the presence of SFA (grass fed animals) and a positive association with UFA, which is more frequently observed in animals fed diets rich in concentrate. However, no differences in sensory scores according to the fatty acid composition of meat was observed in the present study ( $P>0.05$ ). This finding might be explained by the fact that both groups received the same diet rich in concentrate (82%), in addition to the low amount of intramuscular fat observed, corresponding to a low concentration of fatty acids in the samples studied.

The scores and descriptive values of the sensory characteristics were associated with the respective quality traits evaluated by instrumental analysis such as shear force and MFI. Positive correlations were

**Table 3. Mean and standard error of sensory analysis and descriptive evaluation of longissimus thoracis muscle samples aged for 21 days, according to backfat thickness class**

Trait <sup>1</sup>	BFT class <sup>2</sup>	
	BFT-3	BFT-6
Aroma	5.08 ± 0.25	4.56 ± 0.25
	Moderately weak	Weak
Flavor	6.00 ± 0.34	5.35 ± 0.34
	Moderately strong	Moderately weak
Texture/tenderness	4.45 ± 0.44	4.04 ± 0.44
	Tender	Tender
Chewiness	5.68 ± 0.39	6.35 ± 0.39
	Medium	Very low
Juiciness	4.83 ± 0.35	5.54 ± 0.35
	Neither dry nor juicy	Slightly juicy

<sup>1</sup>Aroma and flavor: 1 = none to 9 = extremely strong; Texture/tenderness: 1 = extremely tender to 9 = extremely tough; Chewiness: 1 = elastic (rubber) to 9 = very easy swallowing; Juiciness: 1 = extremely dry to 9 = extremely juicy.

observed between REA and marbling score ( $r = 0.56$ ;  $P < 0.05$ ), REA and cold carcass weight ( $r = 0.39$ ;  $P < 0.05$ ), and cold carcass weight and BFT ( $r = 0.42$ ;  $P < 0.01$ ). *Bos indicus* animals, which exhibit greater muscle growth performance, tend to reach mature weight earlier and thereafter accelerate the growth rate of subcutaneous and intramuscular adipose tissue (SILVEIRA *et al.*, 2010), a fact resulting in meat products with a higher marbling degree. The marbling fat is the last to be deposited and its low concentration may compromise the juiciness, palatability and tenderness of strip loin of Nellore animals, since a minimum lipid content of 3% contributes to obtain a tender and juicy meat (roast) (BELEW *et al.*, 2003), a condition not observed in the present study.

Studying *Bos taurus* animals specialized in meat production, HOCQUETIE *et al.* (2012) reported that genetic selection for muscle growth at the expense of fat deposition is the main factor responsible for the production of carcasses with a good amount of lean meat. Although CHARDULO *et al.* (2014) classifies the Nellore breed as a lean meat producer, a correlation could be observed between BFT and cold carcass weight ( $r = 0.42$ ;  $P < 0.05$ ), and between REA and marbling score ( $r = 0.559$ ;  $P < 0.01$ ), demonstrating the existence of a relationship between muscle tissue growth and early carcass finishing.

On the other hand, observing more than 47,000 Nellore animals, ZUIN *et al.* (2012) found a low genetic correlation between REA and BFT and concluded that both traits should be included in selection indices of the breed. In the present study, when the animals were evaluated independently of BFT class,

no correlation was observed between shear force and MFI ( $r = 0.010$ ;  $P > 0.05$ ), demonstrating the lack of a relationship between enzymatic proteolysis rate after slaughter and meat tenderness. Nevertheless, according to CULLER *et al.* (1978), the MFI is inversely proportional to shear force ( $r = -0.70$ ;  $P < 0.01$ ), with higher MFI values being associated with higher postmortem proteolytic activity which results in lower shear force values.

Additionally, the MFI can explain more than 50% of the variation in meat tenderness (CULLER *et al.*, 1978). In this respect, although Nellore animals exhibit a specific growth pattern when raised in intensive productions system, thus providing carcasses with highly homogenous characteristics, MORALES *et al.* (2003) observed wide phenotypic variation in meat tenderness evaluated based on shear force and MFI. These variations can be attributed in some cases to the low subcutaneous fat content of the carcass.

Similarly, a more consistent ( $R^2 = 0.15$ ) and inversely proportional ( $P < 0.05$ ) relationship was observed between shear force and MFI in animal with better carcass finishing (BFT > 6.0 mm) as shown in Figure 1.

Scattered shear force values in relation to the increase in MFI were observed for samples with a BFT of less than 3.0 mm. Although the MFI is associated with higher postmortem proteolytic activity and consequently with lower shear force values (CHAMBAZ *et al.*, 2003), in many cases the MFI in combination with shear force can be used as a tool to detect problems of tenderness caused

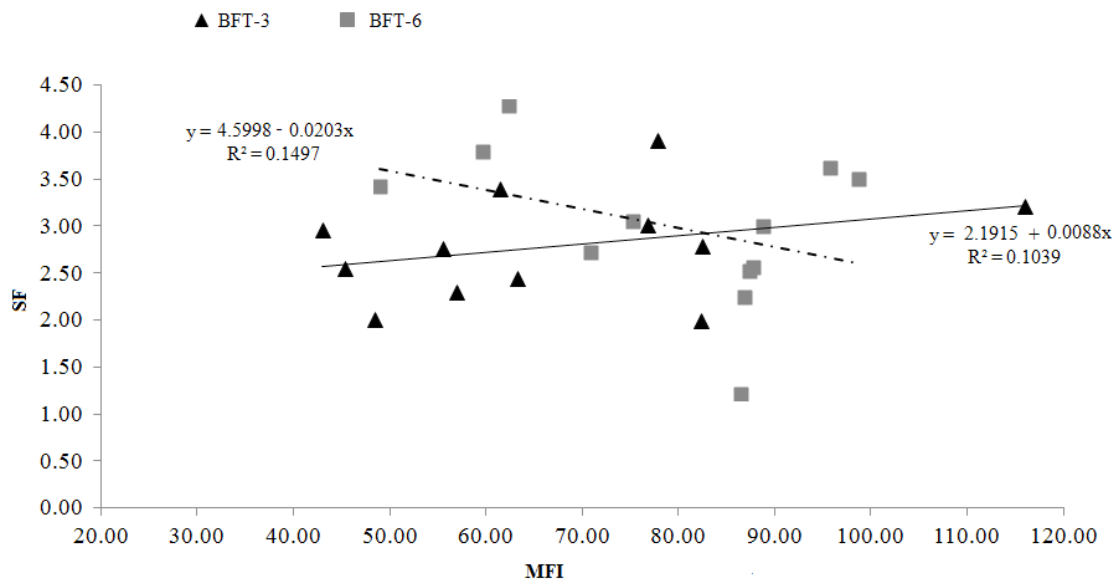


Figure 1. Relationship between shear force (SF) and myofibrillar fragmentation index (MFI) in longissimus thoracis muscle samples of Nellore animals, according to backfat thickness class.

by the post-slaughter cooling process at the slaughterhouse, as observed in the present study.

Using the MFI as an indicator of enzymatic proteolysis, it can be observed that increases in this trait improve the sensory evaluation of aroma ( $r = 0.43$ ;  $P < 0.05$ ), juiciness ( $r = 0.49$ ;  $P < 0.01$ ), and chewiness ( $r = 0.50$ ;  $P < 0.01$ ). Studying Nellore animals at 24 to 30 months of age, HADLICH *et al.* (2006) indicated intensive feed management and meat aging for 14 days as the main tools to standardize meat quality in *Bos indicus* animals, with positive effects on consumer acceptance of the product.

The study of the effects of fatty acid concentration and profile on beef quality is currently becoming more important, highlighting the observation of increases in SFA concentration accompanied by higher BFT and IMF (DE SMET *et al.*, 2004). However, the results obtained in the present study regarding fatty acids indicate the opposite, with a BFT  $< 3.0$  mm being related to a higher concentration of SFA, whereas meat samples with a BFT  $> 6.0$  mm contained a higher amount of UFA in the IMF composition of LT muscle.

## CONCLUSION

Few differences were observed between the main chemical and morphological meat traits evaluated in longissimus thoracis muscle of the

two classes of Nellore bulls with different BFT. The more consistent relationship between tenderness measured by shear force and myofibrillar fragmentation index in animals with higher BFT indicates possible problems of meat tenderization in animals with leaner carcasses. The observation of higher unsaturated fatty acids concentrations in animals with higher BFT suggests improvement in the sensory perception of meat, especially in beef flavor.

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## REFERENCES

- AMERICAN MEAT SCIENCE ASSOCIATION. **Guidelines for cookery and sensory evaluation of meat**. Chicago: National Live Stock & Meat Board, 1978.
- BELEW, J.B.; BROOKS, J.C.; MCKENNA, D.R.; SAVELL, J.W. WarnerBratzler shear evaluations of 40 bovine muscles. **Meat Science**, v.64, p.507-512, 2003.
- BLIGH, E.G.; DYER, W.J. A rapid method of total lipid extraction and purification. **Canadian Journal of Biochemistry and Physiology**, v.37, p.911- 917, 1959.

- CHAMBAZ, A.; SCHEEDER, M.R.L.; KREUZER, M.; DUFÉY, P.A. Meat quality of Angus, Simmental, Charolais and Limousin steers compared at the same intramuscular fat content. **Meat Science**, v.63, p.491-500, 2003.
- CHARDULO, L.A.L.; SILVEIRA, A.C.; VIANELLO, F. Analytical aspects for tropical meat quality In: LIMA, G.P.P.; VIANELLO, F. **Food quality: safety and technology**. Berlin: Springer. Springer-Verlag Wien, 2014. p.53-62.
- CHRISTENSEN, M.; ERTBJERG, P.; FAILLA, S.; SANUDO, C.; RICHARDSON, R.I.; NUTTE, G.R.; OLLETA, J.L.; PANEA, B.; ALBERTI, P.; JUAREZ, M.; HOCQUETTE, J.F.; WILLIAMS, J.L. Relationship between collagen characteristics, lipid content and raw and cooked texture of meat from young bulls of fifteen European breeds. **Meat Science**, v.87, p.61-65, 2011.
- CROSS, D.R.; MOEN, R.; STANFIELD, S. Training and testing of judges for sensory analysis of meat quality. **Food Technology**, v.32, p.48-54, 1978.
- CRUZ, G.M.; TULLIO, R.R.; ESTEVES, S.N.; ALENCAR, M.M.; CORDEIRO, C.A. Peso de abate de machos não-castrados para produção do bovino jovem. 2. Peso, idade e características da carcaça. **Revista Brasileira de Zootecnia**, v.33, p.646-657, 2004.
- CULLER, R.D.; PARRISH JR., F.C.; SMITH, G.C.; CROSS, H.R. Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. **Journal of Food Science**, v.43, p.1177-1180, 1978.
- DE SMET, S.; RAES, K.; DEMEYER, D. Meat fatty acid composition as affected by fatness and genetic factors: a review. **Animal Research**, v.53, p.81-98, 2004.
- DUARTE, M.S.; PAULINO, P.V.R.; FONSECA, M.A.; DINIZ, L.L.; CAVALLI, J.; SERÃO, N.V.L.; GOMIDE, L.A.M.; REIS, S.F.; COX, R.B. Influence of dental carcass maturity on carcass traits and meat quality of Nellore bulls. **Meat Science**, v.88, p.441-446, 2011.
- FRENCH, P.; O'RIORDAN, E.G.; MONAHAN, F.J.; CAFFREY, P.J.; MOONEY, M.T.; TROY, D.J.; MOLONEY, A.P. The eating quality of meat of steers fed grass and/or concentrates. **Meat Science**, v.57, p.379-386, 2001.
- HADLICH, J.C.; MORALES, D.C.; SILVEIRA, A.C.; OLIVEIRA, H.N.; CHARDULO, L.A.L. Efeito do colágeno na maciez da carne de bovinos de distintos grupos genéticos. **Acta Scientiarum. Animal Sciences**, v.28, p.57-64, 2006.
- HOCQUETTE, J.F.; CASSAR-MALEK, I.; JURIE, C.; BAUCHART, D.; PICARD, B.; RENAND, G. Relationship between muscle growth potential, intramuscular fat content and different indicators of muscle fibre types in young Charolais bulls. **Animal Science Journal**, v.83, p.750-758, 2012.
- INSTITUTO ADOLFO LUTZ. Óleos e gorduras. In: INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. 4.ed. São Paulo: 2008. cap. 16, p.537-629.601.
- KILLINGER, K.M.; CALKINS, C.R.; UMBERGER, W.J.; FEUZ, D.M.; ESKRIDGE, K.M. Consumer visual preference and value for beef steaks differing in marbling level and color. **Journal of Animal Science**, v.82, p.3288-3293, 2004.
- LUDTKE, C.B.; CIOCCA, J.R.P.; BARBALHO, P.C.; DANDIN, T.; VILELA, J.A.; FERRARINI, C. **Abate humanitário de bovinos**. Rio de Janeiro: WSPA, 2012.
- MONSÓN, F.; SANUDO, C.; SIERRA, I. Influence of cattle breed and ageing time on textural meat quality. **Meat Science**, v.68, p.595-602, 2004.
- MORALES, D.C.; CHARDULO, L.A.L.; SILVEIRA, A.C.; OLIVEIRA, H.N.; ARRIGONI, M.D.B.; MARTINS, C.L.; CERVIERI, R.C. Avaliação da qualidade da carne de bovinos de diferentes grupos genéticos. **Acta Scientiarum. Animal Sciences**, v.25, p.171-175, 2003.
- OKA, A.; IWAKI, F.; DOGHO, T.; OHTAGAKI, S.; NODA, M.; SHIOZAKI, T.; ENDOH, O.; OZAKI, M. Genetic effects on fatty acid composition of carcass fat of Japanese Black Wagyu steers. **Journal of Animal Science**, v.80, p.1005-1011, 2002.
- OLIVEIRA, E.A.; SAMPAIO, A.A.; HENRIQUE, W.; PIVARO, T.M.; ROSA, B.L.; FERNANDES, A.R.M.; ANDRADE, A.T. Quality traits and lipid composition of meat from Nellore young bulls fed with different oils either protected or unprotected from rumen degradation. **Meat Science**, v.90, p.28-35, 2012.
- PFLANZER, S.B.; FELÍCIO, P.E. Effects of teeth maturity and fatness of Nellore (*Bos indicus*) steer carcasses on instrumental and sensory tenderness. **Meat Science**, v.83, p.697-701, 2009.
- PFLANZER, S.B.; FELÍCIO, P.E. Moisture and fat content, marbling level and color of boneless rib cut from Nellore steers varying in maturity and fatness. **Meat Science**, v.87, p.7-11, 2011.
- RIBEIRO, E.L.A.; HERNANDEZ, J.A.; ZANELLA, E.L.; SHIMOKOMAKI, M.; PRUDÊNCIO-FERREIRA, S.H.; YOUSSEF, E., RIBEIRO, H.J.S.S.; BOGDEN, R.; REEVES, J.J. Growth and carcass characteristics of pasture fed LHRH immunocastrated, castrated and intact *Bos indicus* bulls. **Meat Science**, v.68, p.285-290, 2004.

- RUBIANO, G.A.G.; ARRIGONI, M.B.; MARTINS, C.L.; RODRIGUES, E.; GONÇALVES, H.C.; ANGERANI, C.N. Desempenho, características de carcaça e qualidade da carne de bovinos superprecoces das raças Canchim, Nelore e seus mestiços. **Revista Brasileira de Zootecnia**, v.38, p.2490-2498, 2009.
- SHACKELFORD, S.D.; WHEELER, T.L.; REAGAN, J.O.; BYRNES, B.L.; KOOHMARAIE, M. Consumer impressions of Tender Select beef. **Journal of Animal Science**, v.79, p.2605-2614, 2001.
- SHACKELFORD, S.D.; KOOHMARAIE, M.; MILLER, M.F.; CROUSE, J.D.; REAGAN, J.O. An evaluation of tenderness of the longissimus muscle of Angus by Hereford versus Brahman crossbred heifers. **Journal of Animal Science**, v.69, p.171-177, 1991.
- SCHOONMAKER, J.P.; LOERCH, S.C.; FLUHARTY, F.L.; TURNER, T.B.; MOELLER, S.J.; ROSSI, J.E.; DAYTON, W.R.; HATHAWAY, M.R.; WULF, D.M. Effect of an accelerated finish program on performance, carcass characteristics, and circulate insulin-like growth factor-I concentration of early-weaned bulls and steers. **Journal of Animal Science**, v.80, p.900-910, 2002.
- SILVEIRA, A.C.; ARRIGONI, M.B.; MARTINS, C.L.; CHARDULO, L.A.L. Produção de Bovinos Superprecoces no Brasil In: PIRES, A.V. **Bovinocultura de Corte**. Piracicaba: FEALQ, 2010. v.2, p.1353-1369.
- STENSTRÖM, H.; LI, X.; HUNT, M.C.; LUNDSTROM, K. Consumer preference and effect of correct or misleading information after ageing beef *longissimus* muscle using vacuum, dry ageing, or a dry ageing bag. **Meat Science**, v.96, p.661-666, 2014.
- TAIT, R.G.; WILSON, D.E.; ROUSE, G.H. Prediction of retail product and trimmable fat yields from the four primal cuts in beef cattle using ultrasound or carcass data. **Journal of Animal Science**, v.83, p.1353-1360, 2005.
- UMBERGER, W.J.; FEUZ, D.M.; CALKINS, C.R.; KILLINGER-MANN, K. U.S. consumer preference and willingness-to-pay for domestic corn-fed beef versus international grass-fed beef measured through an experimental auction. **Agribusiness**, v.18, p.491-504, 2002.
- USDA. United States Standards for Grades of Feeder Cattle. Agricultural Marketing Service. **Livestock and Seed Program**, USDA. Washington, DC. 2000.
- USDA. Livestock and poultry: **World market and trade circular archives**, April, 2013.
- VAZ, F.N.; RESTLE, J.; PADUA, J.P.; METZ, P.A.M.; MOLETTA, J.L.; FERNANDES, J.J.R. Qualidade da carcaça e da carne de novilhos abatidos com pesos similares, terminados em diferentes sistemas de alimentação. **Ciência Animal Brasileira**, v.8, p.31-40, 2007.
- WHEELER, T.L.; KOOHMARAIE, M.; SHACKELFORD, S.D. **Standardized Warner-Bratzler Shear Force procedures for meat tenderness measurement**. Roman L. Hruska U. S. Meat Animal Research Center, 1997. Available: <http://afrsweb.usda.gov/SP2UserFiles/Place/30400510/1997500068.pdf>. Access: 20 set. 2015.
- ZUIN, R.G.; BUZANSKAS, M.E.; CAETANO, S.L.; VENTURINI, G.C.; GUIDOLIN, D.G.F.; GROSSI, D.A.; CHUD, T.C.S.; PAZ, C.C.P.; LÔBO, R.B.; MUNARI, D.P. Genetic analysis on growth and carcass traits in Nelore cattle. **Meat Science**, v.91, p.352-357, 2012.