FREE THEMED ARTICLES

DOI: http://dx.doi.org/10.12957/demetra.2015.14293

Nutritional and qualitative values of bovine beef (*Longissimus thoracis*) from organic and conventional production systems

Ana Paula Costa Rodrigues Ferraz[1]
Jessica Moraes Malheiros[2]
Renata Maria Galvão de Campos Cintra[3]
Luis Artur Loyola Chardulo[4]

[1] Universidade Estadual Paulista "Júlio de Mesquita Filho", Departamento de Química e Bioquímica, Instituto de Biociências, Curso de Nutrição. Botucatu-SP, Brasil.

[2] Universidade Estadual Paulista "Júlio de Mesquita Filho", Departamento de Zootecnia, Faculdade de Ciências Agrárias e Veterinárias, Programa de Pós-Graduação em Genética e Melhoramento Animal. Botucatu-SP, Brasil.

[3] Universidade Estadual Paulista "Júlio de Mesquita Filho", Departamento de Educação, Instituto de Biociências. Botucatu-SP, Brasil.

[4] Universidade Estadual Paulista "Júlio de Mesquita Filho", Departamento de Nutrição e Melhoramento Animal, Faculdade de Medicina Veterinária e Zootecnia. Botucatu-SP, Brasil.

Corrrespondence
Jessica Moraes Malheiros
E-mail: jessicamalheiros@yahoo.com.br

Abstract

This study aimed to evaluate the effects of livestock production in organic and conventional management system in relation to the meat quality of Nellore male cattle (*Bos indicus*). Eight animals raised organically and 15 animals produced under conventional system finished in feedlot for 90 days were used. After slaughter, the carcasses were cooled within 24 to 48 hours, and two samples of the *Longissimus thoracis* were collected with approximately 2.54 cm thick between the 12^{th} to 13^{th} ribs of the left half of each animal. Chemical characteristics were evaluated, such as total lipids (TL) and myofibrillar fragmentation index (MFI). Additionally, characteristics such as shear force (SF), rib eye area (REA), marbling index (MI), backfat thickness (BFT), centesimal composition, total losses (LT) and instrumental coloring were evaluated. The organic samples showed best results for instrumental color, the most important item considered at the time of purchase. The average shear force was lower for organic meat and is positively related with tenderness. Significant differences between the two groups can also be observed in the total lipid analysis, fat thickness and moisture content, which showed higher values than in the animals finished in feedlot.

Key words: Backfat Thickness. Softness. Meat Quality. Moisture of the Meat.

Introduction

Healthy eating has attracted growing interest of consumers regarding the consumption of organic foods, which are considered beneficial, nutritious products and less dangerous to health, in view of the massive commercialization of industrial foods and less appreciation of traditional foods in the Brazilians' diet.[1]

In Brazil, there has been a significant and constant increase of organic products, with a growth of 40% in sales in 2010 compared to 2009, totaling R$ 350 million. Thus, there is a large foreign market potential to be conquered, mainly due to the relationship of organic farming with the essence of agroecology and food safety.[1-3]

In the segment of organic livestock, prevention of diseases has been phased out, and the use of allopathic medications (including antibiotics) has decreased. Animals are fed with foods from animal sources, maintaining the health and well-being of the animals, as shown by the slaughtering of 13,800 head/year of organic cattle from 18 certified farmers. In addition, there has been efforts by the population to preserve the environment and increase productivity and profitability. [4]

The main negative factor influencing the organic market is price, often higher when compared to the conventional product, and considered one of the key obstacles to the development of the organic management system in Brazil.[5] The aspects commonly observed by consumers when purchasing beef are color, visible fats, price and cuts.[6]

Estimates show that beef production in Brazil will grow significantly, from 29% from 2013 to 2023, increasing its global market share by 20%. Approximately 27 million head were slaughtered in 2013 compared to the 24 million head in 2012. Considering these parameters, Brazil occupies an outstanding position in beef production.[7,8]

Nellore cattle and their crosses comprise the Brazilian herd, and a raising system that enhances meat tenderness is vital, which is considered the main organoleptic characteristic of meat quality in the consumer's market.[9] An adequate fat cover and good marbling are also key meat quality components, with direct impact on the meat tenderness and palatability.[10,11]

In this context, the goal of this work was to examine the direct influences of the diverse production systems regarding the chemical composition of the meat and quality of the *Longissimus thoracis* muscle of Nellore cattle, aiming to the consumers market and meat technology associated with food safety.

Material and Methods

Animals and sample collection

A total of 23 Nellore animals (*Bos indicus)* were used, 15 of them that were raised in feedlots in three different certified farms related to groups of Animal Breeding in the region of Palmeiras de Goiás-GO, Campo Grande-MS and Bataguassu-MS, and eight animals raised under commercial organic management in the southeastern region, having the certification stamp as required by law. After slaughter in a commercial slaughterhouse in 2013, two samples/steaks with one inch thick (2.54 cm) each were cut from the left half of the animal, between the 12^{th} and 13^{th} ribs, properly vacuum packed and immediately taken to the freezer for further laboratory analyses in the Laboratory of Meat Science of the Department of Animal Breeding and Nutrition (FMVZ-UNESP), in Botucatu-SP.

Shear force (SF) and total losses

To determine the shear force, it was used the mechanical equipment SALTER *Warner-Bratzler Shear Force,* with a capacity of 25 kg and shearing speed of 20 cm/minute. Test was carried out using the standardized procedure proposed by Wheeler et al.,[12] according to which the samples should be cooked to an inner temperature of 71ºC. Shearing consisted of half-inch cylinders cut lengthwise to the muscle fibers. To ensure better accuracy of results, eight measurements per sample were made and expressed in kilograms (Kg).

During the samples cooking for analysis of the shear force, the necessary data for calculation of total losses (evaporation and dripping) were collected.

Instrumental color of meat

Measurement of the samples meat color was made by a KONICA MINOLTA - CR 400 colorimeter (*Minolta Co. Ltd*.), following the method described ty Renerre,[13] through which the equipment was calibrated to the standard color in the *CIE* L^* a^* b^* and adopted the absolute measurements of brightness coordinates (L^*), red color (a^*) and yellow color (b^*).

Rib-eye area (REA), thickness of subcutaneous fat (TSF) and marbling ratio (MR)

To determine the rib-eye area (REA), it was used the quadrants method of points expressed in cm^2,[14] as well as the thickness of subcutaneous fat (TSF), measured with a caliper and expressed in millimeters (mm). For analysis of the MR, it was used a visual grading scale adapted by the Meat Certification Laboratory to the marbling patterns usually found in the national cattle herd.

Centesimal composition

Gross chemical composition was determined according to the techniques indicated by the Association of Analytical Communities (AOAC).[15] To determine the moisture content, 10g of each sample were kept in oven at a temperature of 105ºC for at least 12 hours and cooled in a desiccator for at least two hours. The dry matter obtained from each sample was incinerated in a muffle at a temperature of 550-600ºC for determination of the ash content.

Total lipids (TL)

Counting of total lipids followed the method described by Bligh & Dyer,[16] using 3 g of raw ground meat, 10 ml of chloroform, 20 ml of methanol and 8 ml of distilled water. After the samples homogenization, they were placed on a horizontal shaking table for 30 minutes.

Subsequently, 10 ml of chloroform and 10 ml of aqueous solution of 1.5% sodium sulfate were added, centrifuged at 1,000Xg, the supernatant was discarded, and the remaining solution was filtered in filter paper. Five milliliters of the filtrated were measured and transferred to a 50ml beaker previously weighed, maintained in oven at 110ºC until total evaporation of the solvent; then is was cooled in desiccator (O/N) and weighed.

Myofibrillar fragmentation index (MFI)

The myofibrillar fragmentation index (MFI) was determined according to the method described by Culler et al.[17] and adapted by the Laboratory of Meat Science of the Department of Animal Breeding and Nutrition (FMVZ-UNESP) in Botucatu-SP.

Three grams of homogenized muscle was used in *Ultra-turrax* at 18,000 rpm in 30 ml of buffer (TMFI) at 2ºC, and the samples were centrifuged at 1,000Xg for 15 minutes at 2ºC, and the supernatant was discarded. This procedure was replicated twice. The pellet was then re-suspended in 15 ml of TMFI at 2ºC and filtered. Determination of myofibrillar proteins was made by means of the biuret method. [18] For determination of MFI, the samples were prepared with TMFI for a total final volume of 8 ml and 0.5 mg/ml of protein concentration, and then absorbance was read on a spectrophotometer at 540nm wavelength.

Experimental design and statistical analysis

Average values of eight shear force (SF) measurements were analyzed according to the simple variance analysis model, including only the treatment effect and error. The same model was used for all measurements made just once in the samples (MR, total loss, REA, and TSF). Analyses of other variables, which were measured repeatedly in each sample (MFI, color, TL, moisture and centesimal composition), were carried out following a split-plot design model, where each animal is a plot and the measurements taken over time the plot subdivisions. The model of analysis for these characteristics was as follows:

$$Y_{ijk} = u + T_i + a_{ij} + M_k + I_{ik} + e_{ijk}$$

where:

Y_{ijk} = observed characteristic value (MFI, color, TL, centesimal and moisture) of the animal sample j, belonging to treatment i, in time k.

u = overall average;

T_i = Effect of experiment i (i=1,2);

a_{ij} = Effect of animal j (j=1,..12); within treatment i;

Mk = Effect of time k where the measurement was made (k=1,2 or k=1,...5, depending on the variable examined);

I_{ik} = effect of the interaction between the time of measurement and treatment.

e_{ijk} = random error associated with each particular observation.

The averages were compared by the Tukey's test. The analyses for the simple model were made using PROC GLM and the other analyses using PROC MIXED, both of the SAS system.[19]

Results and Discussion

According to Figueiredo & Soares,[4] it was found that in the Mid-West, North and Northeast regions of the country, sales of organic foods are insignificant, representing only 6% of the marketing channels, which can be associated with the need to obtain samples from the southeast. The commercial origin of the organic samples in this work became more feasible because of the insufficient number of certified organic farms or slaughterhouses, a requirement highly valued by consumers.[20]

Besides meat certification, color is the main sensory aspect that consumers observe when buying meat. The beef color can be classified, according to Abularach et al.,[21] as: light colored meats (L*>38.51), with average redness (low a*<14.83; high a*> 29.27) and high yellowness (b*>8.28). Thus, we can see from Table 1 that the organic samples had higher brightness, higher redness and yellowness, compared to the conventional products.

Table 1. Descriptive statistical values of instrumental color (L*, a* and b*) measured in Nellore animals (*Bos indicus*), raised in different farming systems Botucatu-SP, 2013.

Variables	Conventional	Organic
Brightness (L*)	31.8 ± 2.93^a	41.3 ± 0.76^b
Red (a*)	12.3 ± 2.34^a	21.4 ± 1.97^b
Yellos (b*)	5.4 ± 1.57^a	10.6 ± 0.41^b

[a,b] Means followed by different lowercase letters in the same row are significantly different ($p<0.05$) by the Tukey's test.

The redness (a*) observed in the present study for the samples of organically-raised animals was higher on average than that of the animals raised in the conventional system. This fact can be justified by the differences found in the different management and production systems. Sañudo et al.[22] report that beef cattle raised on pasture can have a higher amount of myoglobin and higher number of red fibers in the muscle due to the activities and physical effort required by the animals to be fed. However, according to Felício,[23] high myoglobin concentration is related to late slaughtering of the animals, which have longer maturity.

The meat color can be associated with the physical condition of meat, especially the surface pH and other factors such as hydration and status of muscle proteins. High yellowness in beef fat is often classified by consumers as older animals, but animals finished on pasture, as in our study, usually present high yellow contents, which may be associated with high amounts of β-carotene, which is beneficial to human health.[24]

Concerning the objective analyses for beef tenderness, the results of the shear force tests were different for the organic and conventional meats (Table 2). The organic animals showed average SF lower than the conventional animals. According to Oliveira,[25] acceptable SF values for tenderness are those falling below 4.5kg. According to Koohmaraie,[26] meats with SF lower than 5.5kg can be considered tender after cooking; and average SF values below 3.5kg can indicate the capacity of all individuals to produce meat with SF below 5.5kg[27] – that is, cattle herds with 100% tender meat, as found in the present study.

Table 2. Means of physical analyses of the *Longissimus thoracis* muscle (12^{th}-13^{th} ribs) of Nellore animals raised in conventional and organic systems. Botucatu-SP, 2013.

Variables	Conventional	Organic
REA (cm^2)	66 ± 5.64^a	84 ± 1.41^b
TSF (mm)	4.6 ± 1.54^a	6 ± 0.10^b
MR	2.6 ± 0.3	2.2 ± 0.07
SF (kg)	5.4 ± 1.12^a	2.2 ± 0.15^b
TL (%)	24.2 ± 3.96	26.0 ± 1.01

REA = rib-eye area; TSF = thickness of subcutaneous fat; MR = marbling ratio, SF = shear force; TL = total loss.
[a,b] Means followed by different lowercase letters in the same row are significantly different ($p<0.05$) by the Tukey's test.

Various studies report that Nellore cattle beef has higher SF values, compared to crossbred individuals raised in feedlots[28,29] as well as on forage-based feeding.[30] The higher SF values found in Nellore beef can be partially explained by the higher activity/concentration of calpastatin, protein that regulates the enzymatic activity of calpains, leading to decreased myofibrillar proteolysis with consequent reduction of the meat tenderness.[28]

In the assessment of the parameters observed for the animal development, the value found for the rib-eye area (REA) was higher in organically-raised animals than in the conventional system. This characteristic is examined in the *Longissimus thoracis* muscle and has a good relationship with the amount of muscles present in the carcasses. Thus, it contributes to estimating meat cuts yields, showing a high correlation with the amount of edible tissue.[11,29,31]

The discrepancy of the REA values found in the diverse groups can be explained by the animal development conditions, because there are changes in the carcass composition in relation to the amount of muscle, fat and bones. Such deposition may be influenced by genetic and environmental factors. The nervous and bone tissues have an earlier maturing, while the muscular development is intermediate and the fat tissue usually develops later. Distribution of the adipose tissue has a direct importance in the carcass quality, protecting the muscle from cold shortening, characterized by the drastic reduction of muscle sarcomeres before *rigor mortis*.[32]

According to Alves & Mancio,[10] the impact of feed on the meat tenderness is primarily associated with the degree of finishing (backfat thickness) and intramuscular fat content in carcass. Well-finished animal carcasses, with adequate fat cover and good marbling, usually have tender meat when tested in laboratory or in tasting panels.

Working with 24-to-30-month-old Nellore animals, Hadlich et al.[33] observed few individual variations in the carcass characteristics and meat quality. The authors attributed the similarity of the assessed characteristics to the finishing system of animals confined in feedlots, which tends to standardize carcasses and their respective beef products.

In the present study, a significant difference was found between the groups assessed for TSF, in which the conventional individuals showed adequate finishing, probably due to the feedlot system used, thus presenting less deposition of subcutaneous fat. The adipose tissue has caused disapprovals because it has been accounted for the emergence of cardiovascular diseases, arteriosclerosis, cholesterol, among others.

On the other hand, according to Aferri et al.,[34] and Prado et al.,[35] animals raised in feedlots or with alternative diets do not present a significant relation with the characteristics of carcass, rib-eye area and backfat thickness, among other characteristics that are examined at the time of meat analysis, showing that forage may be an effective and nutritious feeding source.[7]

To modern consumers, taste and nutritional value are two key attributes of meat quality. The tendency is to focus on the production of lean meat, with a minimum excess of visible fat; on the other hand, subcutaneous and intramuscular fat contributes to the meat quality.[36,37]

The values indicated in Table 3 for total lipids also favor the organic meat, showing a possible positive correlation between the lipid contents and tenderness of organic beef, once the amount of fat is associated with the meat quality.[11] On the other hand, studies on pasture-raised cattle, the animals are often slaughtered with lower weights, producing carcasses with lower percentages of lipids and, consequently, delivering harder meats.[38]

Table 3. Means of chemical analyses of the *Longissimus thoracis* muscle of Nellore animals raised in the conventional and organic systems. Botucatu-SP, 2013.

Variables	Conventional	Organic
TL (%)	0.57 ± 0.24^{a}	1.5 ± 0.79^{b}
MFI	46.7 ± 18.01^{a}	21.3 ± 1.87^{b}
Moisture (%)	77.3 ± 7.11^{a}	98.6 ± 0.21^{b}
Ash	1.1 ± 1.23	1.3 ± 0.17

TL = total lipids; MFI = myofibrillar fragmentation index.

[a,b] Means followed by different lowercase letters in the same row are significantly different ($p<0.05$) by the Tukey's test.

The increased amount of lipids in the *Longissimus thoracis* muscle of Nellore animals indicated a greater deposition of marbling fat;[39] however, these animals present little lipid synthesis in the muscle tissue and, consequently, a lower percentage of total lipids in the meat.[27] Despite the significant difference of TL between the different groups, both presented a low deposition of intramuscular fat, as usually found in *Bos indicus* animals.

The average marbling ratio was classified as low and in disagreement with the TL values, which can be explained by the fact that marbling results from subjective evaluations of the meat; therefore one can rely on the TL analysis because of its objectivity.

The importance of *postmortem* proteolysis was also cited by authors who reported the existence of a strong connection between meat tenderness and the myofibrillar fragmentation index.[17] In this regard, the values found for MFI were higher in the feedlot-raised animals compared to the organic ones (Table 3), contradicting the SF values found. These are inversely proportional measures, where lower SF is directly related to higher myofibrillar proteolysis. The findings of this study indicate that there are significant numerical variations between the animals of both experimental treatments.

There were no significant differences between the total ash contents in the groups studied, but there was a small difference in moisture contents. The animals raised in the organic system showed higher moisture ratios compared to the feedlot animals, which can be associated with beef juiciness.

In a study conducted by Abularach et al.,[21] moisture and lipids values were reported to be 75.65% and 1.71%, respectively, for 24-month old Nellore calves, values that differ from those found in this study and may be related with the animal age at the slaughtering time. Silva et al.[40] found values for the *Longissimus dorsi* muscle of Eurozebu heifers ranging from 74.3 to 75.2%, and Vaz et al.[41] obtained higher moisture values in the meat of whole animals compared to castrated Charolês x Nelore animals (71.9 *versus* 70.8%). Rodrigues et al.[42] and Hautrive et al.[43] found moisture values nearly 73.5%. And the total loss values were similar to those found by Felício et al.,[44] of 25.18%, for Nellore calves meat. When meat is cooked, water loss affects the product yield, with impact on its palatability and acceptability.[45,46] Even though the meat cuts analyzed in this study have presented satisfactory values and that research efforts on organic foods are constantly carried out, it is noteworthy that factors such as soil, climate, genetics and post-harvest or post-harvest periods have a direct impact on the foods composition,[47] which emphasizes the chemical differences found in this study.

It is also noticeable the inconsistent tenderness of Nellore bovine meat when compared to other races commonly raised in Brazil and other countries. Thus, improvements in animals breeding in research centers of meat, as well as in the preservation technologies and sustainability of forage-raising lands, are needed.[7,48]

Bovine meat is an important food present in people's diets because of its nutritional aspects as well as for the agribusiness. It is one of the meat varieties largely consumed in the United States, Brazil, Japan and China, with emphasis on Brazil, the second largest exporter in the world. Therefore, possible relations between the meat quality and nutritional composition were examined, based on data generated from physicochemical analyses of meat cuts, as well as their possible relations with the meat nutritional composition and quality of different groups of animals raised in different production systems.

Conclusions

Nellore (*Bos indicus*) animals show great capacity to produce beef, which was observed in the group of conventional and organic animals through the values found for REA and deposition of subcutaneous fat (TSF). However, in general, due to the lower lipid synthesis and high loss values during cooking, they represent a less value-added product with respect to the meat quality.

Organic bovine meat showed significant differences, involving quality aspects in relation to the bovine meat usually consumed by people. Thus, further studies on this kind of food and related technologies involved in the production system and sustainability are of key importance in the supply chain links and consumers market.

Acknowledgements

We would like to thank to the Institutional Scientific Initiation Scholarship Program (*PIBIC*) and to the São Paulo Research Foundation (FAPESP) for the financial support.

References

1. Mooz ED, Silva MV. Organic food in the national and international scenarios. Nutrire: Rev. Soc. Bras. Alim. Nutr. 2014; 39(1):99-112.
2. Instituto Brasileiro de Geografia e Estatística. Censo Agropecuário 2006 [Internet]. Rio de Janeiro: IBGE. [acesso em dez. 2013]. Disponível em: http://saladeimprensa.ibge.gov.br
3. Food and Agriculture Organization of the United Nations [Internet]. [acesso em: fev. 2014]. Disponível em: https://www.fao.org.br/
4. Figueiredo EAP, Soares JPG. Sistemas orgânicos de produção animal: dimensões técnicas e econômicas. Anais da 49ª Reunião Anual da Sociedade Brasileira de Zootecnia: A produção animal no mundo em transformação; 23-26 jul. 2012; Brasília.
5. Stolze M, Lampkin N. Policy for organic farming: rationale and concepts. Food Policy 2009; 34:237-244.
6. Robbins K, Jensen J, Ryan KJ, Homco-Ryan C, McKeith FK, Brewer MS. Consumer attitudes towards beef and acceptability of enhanced beef. Meat Science 2003; 65(2):721-729.
7. Lobato JFP, Freitas AK, Devincenzi T, Cardoso LL, Tarouco JU, Vieira RM, et al. Brazilian beef produced on pastures: Sustainable and healthy. Meat Science 2014 98(3):336-345.
8. Associação Brasileira das Indústrias Exportadoras de Carnes [Internet]. São Paulo. [acesso jul. 2014]. Disponível em: http://www.abiec.com.br
9. Highfill CM, Esquivel-Font O, Dikeman ME, Kropf DH. Tenderness profiles of ten muscles from F1 Bos indicus x Bos taurus and Bos Taurus cattle cooked as steaks and roasts. Meat Science 2012; 90(4):881-886.
10. Alves DD, Mancio AB. Maciez da carne bovina: uma revisão. Revista FZVA 2007; 14(1):193-216.
11. Costa EC, Restle J, Brondani IL, Perottoni J, Faturi C, Menezes LFG. Composição física da carcaça, qualidade da carne e conteúdo de colesterol no músculo Longissimus dorsi de Novilhos Red Angus Superprecoces, Terminados em confinamento e abatidos com diferentes pesos. R. Bras. Zootec. 2002; 31(1)417-428.
12. Wheeler TL, Koohmaraie M, Shackelford SD. Standardized Warner- Bratzler Shear Force procedures for meat tenderness measurement. Proc. Recip. Meat Conf. 1995; 50:68-77.
13. Renerre M. La coleur de la viande et sa mesure. Bulletin Technique, C.R.V.Z., Theix, I.N.R.A. 1982; 47:47-54.
14. United States Standards for Grades of Feeder Cattle. Agricultural marketing service. Washington, D.C.: Livestock and Seed Program, USDA; 2000.
15. The Association of Analytical Communities. Official methods of analysis. 15ª ed. Arlington: AOAC; 1995.

16. Bling EG, Dyer WJ. A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 1959; 37(8):911- 917.

17. Culler RD, Parrish JR FC, Smith GC, Cross HR. Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. Journal of Food Science 1978; 43(4):1177-1180.

18. Gornall AG, Bardawill CJ, David MM. Determination of serum proteins by means of biuret reaction. J. Biol. Chem 1949; 177(2):751-766.

19. Statistical Analysis System Institute. SAS user's guide: statistics. Cary: Statistical Analysis System Institute; 2011.

20. Velho JP, Barcellos JOJ, Lengler L, Elias SA, Oliveira, TE. Disposição dos consumidores porto-alegrenses à compra de carne bovina com certificação. R. Bras. Zootec. 2009; 38(2):399-404.

21. Abularach MLS, Rocha CE, Felício PE. Características de qualidade do contrafilé (m. L. dorsi) de touros jovens da raça Nelore. Ciência Tecnologia de Alimentos 1998; 18(2):205-210.

22. Sañudo C, Santolaria MP, Maria GA, Osório M, Sierra I. Influence of carcass weight on instrumental and sensory lamb meat quality in intensive production systems. Meat. Science 1996; 42(2):195-202.

23. Felício PE. Qualidade da carne bovina: características físicas e organolépticas. In: Anais da 36ª Reunião Anual da Sociedade Brasileira de Zootecnia; 1999. Porto Alegre. Brasília: Sociedade Brasileira de Zootecnia; 1999. p. 89-97.

24. Rossato LV, Bressan MC, Rodrigues EC, Gama LT, Bessa RJB, Alves SPA. Parâmetros físico-químicos e perfil de ácidos graxos da carne de bovinos Angus e Nelore terminados em pastagem. R. Bras. Zootec. 2010; 39(5):1127–1134.

25. Oliveira AL. Maciez da carne bovina. Cadernos Técnicos de Veterinária e Zootecnia 2000; 33:7-18.

26. Koohmaraie M. Muscle proteinases and meat aging. Meat Science 1994; 36:93-104.

27. Chardulo LAL, Silveira AC, Vianello F. Analytical aspects for tropical meat quality assessments. In: Lima GPP; Vianello F. Food Quality, Safety and Technology. Springer-Verlag Wien; 2013. p. 53-62.

28. Lage JF, Paulino PV, Filho SC, Souza EJ, Duarte MS, Benedeti PD, et al. Influence of genetic type and level of concentrate in the finishing diet on carcass and meat quality traits in beef heifers. Meat Science 2012; 90(3):770-774.

29. Pereira PMRC, Pinto MF, Abreu UGP, Lara JAF. Características de carcaça e qualidade de carne de novilhos superprecoces de três grupos genéticos. Pesq. Agropec. Bras. 2009; 44(11):1520-1527.

30. Heinemann RJB, Pinto MF, Romanelli PF. Fatores que influenciam a textura da carne de novilhos Nelore e cruzados Limousin x Nelore. Pesq. Agropec. Bras. 2003; 38(8):963-971.

31. Ribeiro EL, Hernandez JA, Zanella EL, Shimokomaki M, Prudêncio-Ferreira, SH, Youssef E, et al. Growth and carcass characteristics of pasture fed LHRH immunocastrated, castrated and intact Bosindicus bulls. Meat Science 2004; 68(2):285-290.

32. Giusti J. Expressão de genes relacionados à qualidade da carne do músculo Longissimus dorsi em Nelore (Bos indicus) e canchim (5/8 Bos taurus x 3/8 Bos indicus) [Tese]. Jaboticabal, SP: Universidade Estadual Paulista, Faculdade de Ciências Agrárias e Veterinárias; 2011. p. 74.

33. Hadlich JC, Morales DC, Silveira AC, Oliveira HN, Chardulo LAL. Efeito do colágeno na maciez da carne de bovinos de distintos grupos genéticos. Acta Sci. Anim. Sci. 2006; 28(1):57-62.

34. Aferri G, Leme PR, Silva SL, Putrino SM, Pereira ASC. Desempenho e características de carcaça de novilhos alimentados com dietas contendo diferentes fontes de lipídios. R. Bras. Zootec 2005; 34(5):1651-1658.

35. Prado IN, Pinheiro AD, Alcalde CR, Zeoula LM, Nascimento WG, Souza NE. Níveis de substituição do milho pela polpa de Citrus Peletizada sobre o desempenho e características de carcaças de bovinos mestiços confinados. Rev. Bras. Zootec. 2000; 29(6): 2135-2141.

36. Wood JD. Consequences for meat quality of reducing carcass fatness. In: Wood JD, Fisher AV, editors. Reducing fat in meat animals. England: Elsevier Science Publishers; 1990. p. 344-389.

37. Webb EC. Manipulating beef quality through feeding. South African Animal Science 2006; 7:5-15.

38. Bridi AM, Constantino C. Qualidade e avaliação de carcaças e carnes bovinas]Internet]. GPAC. [acesso em jul. 2014] Disponível em: http://www.uel.br/grupo-pesquisa/gpac/pages/arquivos/Qualidade%20e%20Avaliacao%20de%20Carcacas%20e%20Carnes%20Bovinas.pdf

39. Fortes MRS, Curi RA, Chardulo LAL, Silveira AC, Assumpção MEOD, Visintin JA, et al. Bovine gene polymorphisms related to fat deposition and meat tenderness. Genetics and Molecular Biology 2009; 32(1):75-82.

40. Silva RG, Prado IN, Matsushita M, Souza NE. Dietary effects on muscle fatty acid composition of finished heifers. Pesq. Agropec. Bras. 2002; 37(1):95-101.

41. Vaz FN, Restle J, Feijó GLD, Restle J, Brondani IL, Rosa JRP, et al. Qualidade e composição química da carne de bovinos de corte inteiros ou castrados de diferentes grupos genéticos Charolês x Nelore. Rev. Bras. Zootec. 2001; 30(2):518-525.

42. Rodrigues VC, Andrade IF. Características físico-químicas da carne de bubalinos e de bovinos castrados e inteiros. Rev. Bras. Zootec. 2004; 33(6):1839-1849.

43. Hautrive TP, Marques AC, Kubota EH. Avaliação da composição centesimal, colesterol e perfil de ácidos graxos de cortes cárneos comerciais de avestruz, suíno, bovino e frango. Alimento e Nutrição 2012; 23(2):327-334.

44. Felício PE. Carcass composition and quality traits of zebu steers slaughtered in the state of São Paulo Brazil [Tese]. Kansas: Kansas State University; 1981.

45. Kondjoyan A, Oillic S, Portanguen S, Gros JB. Combined heat transfer and kinetics model to predict cooking loss during heat treatment of beef meat. Meat Science 2013; 95(2):336-344.

46. Modzelewska-Kapitula M, Dabrowska E, Jankowska B, Kwialkowska A, Cierach M. The effect of muscle, cooking method and final internal temperature on quality parameters of beef roast. Meat Science 2012; 91(2):195-202.

47. Ferraz APCR, Malheiros JM, Cintra RMG. A produção, o consumo e a composição química dos alimentos orgânicos. Rev. Simbio-logias 2013; 6(9):31-42.

48. Elzo MA, Johnson DD, Wasdin JG, Driver JD. Carcass and meat palatability breed differences and heterosis effects in an Angus-Brahman multibreed population. Meat science 2012; 90(1): 87-92.

Received: December 29, 2014
Accepted: January 14, 2015