International Food Research Journal 23(4): 1523-1530 (2016)
Journal homepage: *http://www.ifrj.upm.edu.my*

# Influence of breed on beef and intramuscular fat quality from nellore *(Bos indicus)* and wagyu *(Bos taurus)* crossbreed cattle

[1*]Dias, L.S., [2]Hadlich, J.C., [3]Luzia, D.M.M. and [1]Jorge, N.

[1]*Department of Food Engineering and Technology, São Paulo State University (UNESP), Cristóvão Colombo Street, 2265, Jardim Nazareth, 15.054-000, São José do Rio Preto, SP, Brazil*
[2]*Department of Animal Breeding and Nutrition, São Paulo State University (UNESP), Rubião Junior District, no number, 18618-970, Botucatu, SP, Brazil*
[3]*Department of Exact and Earth Sciences, Minas Gerais State University (UEMG), Professor Marcos Palmério Avenue, 1001, Bairro Universitário, 38200-000, Frutal, MG, Brazil*

**Article history**

*Received: 3 November 2015*
*Received in revised form: 23 December 2015*
*Accepted: 6 January 2016*

**Keywords**

*Beef products*
*Animal fats*
*Fatty acids*
*Physical properties*
*Cholesterol*

**Abstract**

In the meat market, there are different types of meat cuts, from different breed cattle, that reflect on the beefs purchase values. Thus, the aim of this study was to evaluate the differences between the quality of beef and intramuscular fat from Nellore and Wagyu cattle, and verify their capacity of add value to the beefs in the market. Three animals from Nellore and three from Wagyu were slaughtered, and the pieces of sirloin steak *(M. longissimus thoracis)* and chuck steak *(M. trapezius Pars cervicalis)* were collected. The beefs were evaluated as to nutritional composition, color, losses by cooking, and shear force. The fats were extracted by cold extraction with petroleum ether and analyzed as to cholesterol level and fatty acid composition. Wagyu sirloin and chuck steaks showed higher fat content and marbling, factors that reflected on its softness, especially the chuck steak of this breed, which proved to be tender, although it is considered a stiffer cut. As a conclusion, the softness of the Wagyu beefs and their high amount of intramuscular fat improve quality and add value to these products, making them gourmet foods destined to a specific target audience.



## Introduction

In Brazil, Nellore *(Bos indicus)* breed, or zebu cattle, prevails as beef cattle, in whose production is adopted finishing in short periods of time and pasture-based fattening, for higher profit, resulting in beef with low level of extra and intramuscular fat, which is harmful for the product's quality and sale price (Silva *et al*., 2009).

On the other hand, Wagyu *(Bos taurus)* breed, of Japanese origin and bull genetics, is characterized by its capacity of intramuscular fat deposition, known as marbling. Fat deposition starts in the calf's tenth month of age and continues for twenty months. The animals need more care during management, besides higher period of weight gain (Gotoh *et al*., 2009; Okumura *et al*., 2012). Due to this fact, they go through genetic crossbreed with Nellore and Angus in order to conform the product value with the Brazilian consumer market, and also for the better adaptation of the animals to Brazilian climate (Ferraz and Felício, 2010).

Besides the type of management, genetics also contributes for technological and sensory characteristics of beef and has influence on the fatty acid profile of the intramuscular fat. The presence of the *Bos indicus* genetics is capable of reducing cut softness, and the presence of *Bos Taurus* genetics is capable of elevating the level of unsaturated fatty acids (Rossato *et al*., 2009; Lage *et al*., 2012).

The acceptance of the meat depends on nutritional and sensory factors, such as protein and lipid content, color, flavor, and softness characteristics (Devine, 2014). Meat marbling directly influences these two factors, because it provides flavor and softness, as well as saturated and unsaturated fatty acids, predominantly palmitic, stearic, and oleic acids (Morales *et al*., 2013). Thus, the aim of this study was to evaluate the influence of breed on the quality of beef and intramuscular fat of pure Nellore and Wagyu three-way crosses (Nellore, Wagyu, Angus) cattle.

## Materials and Methods

### *Animals and diet*

Fifty animals from pure Nellore *(Bos indicus)* and fifty animals from Wagyu three-way crossed (1/4 *B. indicus* + 3/4 *B. taurus*), male, castrated, and originating from the farm "Vó Cidinha" (Nhandeara,

*Corresponding author.
Email: *liaradias@yahoo.com*
Tel: +55 17 3221 2565

São Paulo State, Brazil) were used for the sampling. Feedlot was used with feed composed of cane bagasse, ground corn, citric pulp, peanut bran, and mineral supplement. The age and the confinement time of animals used were those commonly adopted for commercial market, according to the breed. Nellore animals were 35 months old, weighed an average of 507 kg, and had been through 110 days of feedlot; the Wagyu animals were 35 months old, weighed an average of 907 kg, and had been through 656 days of feedlot.

*Slaughter and sample collection*

Slaughter was performed in Frigorífico José Bonifácio Ltda (José Bonifácio, São Paulo State, Brazil). The procedure was carried out according to RIISPOA (1980), respecting the rules of humanitarian slaughter. The carcasses were numbered for each breed, according to the order of entrance in the production line.

In the trimming, inguinal, perirenal, and pelvic fat were removed. After slaughter, the carcasses were immediately taken to the refrigerator at 0–2ºC, where they were kept for 24 h, for resolution of rigor mortis. Bone was performed for collection of sirloin steak (*M. longissimus* t*horacis*), and chuck steak (*M. trapezius Pars cervicalis*). Pieces of approximately 500 g/each, with approximately 10 cm thickness, obtained from the Noix and chuck, vacuum packed, identified, and stored in freezer at –12ºC, until the moment of the analyses.

*Experimental delineation*

Four experimental unit types were delineated: Nellore sirloin steak, Wagyu sirloin steak, Nellore chuck steak, and Wagyu chuck steak. For each experimental unit type, three samples were obtained, one from each animal. The sample analyses were performed in triplicate. Figure 1 presents the explanatory flowchart of the experimental delineation, exemplified by Wagyu cattle, similar procedure was performed for Nellore.

*Methods*

In order to perform the analyses of the proximate chemical composition, beef quality, and fat extraction, described below, the defrosting of the pieces was performed in refrigerator at 4ºC for 24h.

*Proximate chemical composition*

After defrosting, the samples were ground and homogenized before each analytical procedure. Moisture and volatile matter, lipids and ashes were determined according to AOCS official methods

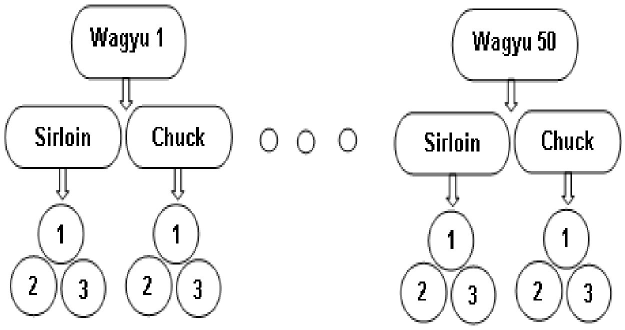


Figure 1. Explanatory flowchart of the experimental design exemplified by the Wagyu cattle

(2009). The protein level was quantified by the method of Kjeldahl (factor of conversion for meats: 6.25), for total calculation of proteins (AOAC, 2005). The calorific value was calculated with correction factor of 4 kcal/g for the protein level, and 9 kcal/g for lipids, according to Merril and Watt (1973).

*Beef quality*

The color was evaluated by using the Minolta Chroma Meter colorimeter, model CR–200 (Minolta Corporation, Ramsey, New Jersey, USA). Calibration was done in a white surface (Y = 93.5, X = 0.3132, y = 0.198). For cooking losses analyses, the meat pieces were cut into 2.54 cm thickness steaks, packed in parchment paper and frozen at –18°C. The defrosting occurred at temperatures between 2 and 5°C for 24 h in refrigerator, with thermometer monitoring until inner temperature between 2 and 5°C. A thermocouple was inserted into the center of each steak. The steaks were placed on a grid supported on a refractory container to collect the meat juice exudate, all previously weighed separately in semi-analytical balance. This set was then taken to a preheated oven at 200°C, maintained until steaks center reached between 40 and 45°C, when they were turned vertically. After this, the heating is continued until the steaks internal temperature of 71°C, when the samples were withdrawn. These were kept at room temperature until complete cooling. Steaks and refractory containers with the grids were weighed to calculate the Losses by Evaporation, Dripping and Total Losses. For the Shear Force Analysis, we used the Warner-Bratzler Shear Force (WBSF) equipment, with a 1.016 mm thickness blade, blunt angularity of 60º and 2.363 cm diameter, and a bar with 1.245 mm thickness and 20 cm/min speed. The cooked steaks were wrapped in thin plastic bags, taken to the refrigerator (4°C) for 24 h, cut in a 1.27 cm diameter cylindrical shape, parallel to the longitudinal direction of the muscle fibers, and subjected to cross-cut by WBSF equipment.

*Fat extraction and quality*

Fat extraction was done by Soxhlet method, according to Ba 3–38 (AOCS, 2009). Each fat was packed in identified amber glass, inertized with gas nitrogen, and stored at –18ºC, until the moment of analyses. Cholesterol level was determined by gas chromatography with previous saponification of the samples (50–80 mg). Saponification was performed according to UMA 0069 method, described by Duchateau *et al*. (2002). Determination of cholesterol content was performed according to Ch 6–91 method of AOCS (2009). The analysis was developed in gas chromatograph CG–2010 (Shimadzu, Chiyoda-ku, Tokyo, Japan), equipped with flame ionization detector (CG–FID), split injector, and automatic sampler. Analysis conditions: fused silica capillary column RTX 5 (30 x 0.25 mm, 0.25 µm film thickness, Restek, Shimadzu, Chiyoda-ku, Tokyo, Japan); column temperature was kept isothermal at 300°C for 10 min. The temperatures used in the injector and in the detector were 280 and 320°C, respectively. Hydrogen was used as carrier gas, with 40 mL/min linear speed. Cholesterol quantification was performed by internal standardization based on the peak areas, and the levels were expressed as mg/kg.

Fatty acid composition was determined through fatty acid methyl esters present in the oils, by transesterification with the use of potassium hydroxide in methanol and n-hexane, according to the procedure described by Ce 2–66 method of AOCS (2009). Analysis was performed in gas chromatograph CG 3900 (Varian Inc., Walnut Creek, CA, USA), with flame ionization detector (CG–FID), split injector, and automatic sampler. A fused silica capillary column CP–Sil 88 (Varian, Walnut Creek, CA, USA), with 60 m length, 0.25 mm internal diameter, and 0.20 µm film thickness was used. Column temperature programming was initiated at 90ºC, for 4 min, heated at 10ºC/min until 195ºC, and kept isothermal for 16 min. The temperatures used in the injector and in the detector were 230 and 250ºC, respectively. Hydrogen was the carrier gas, with 30 mL/min linear speed. Fatty acids were identified by comparison of retention times of pure standards of fatty acid methyl esters with the separated components of samples, and quantification was done by area normalization. A mixture composed of 37 fatty acid methyl esters (Supelco, Bellefonte, USA), from C4:0 to C24:1, with purity between 99.1 and 99.9%, was used as standard.

*Statistical analysis*

The results obtained from the analytical determinations, in triplicate, were subjected to analysis of variance (ANOVA), and the differences between means were tested at 5% probability by Tukey test, using the STATISTICA program, version 7.0.

Table 1. Proximate composition of the beef samples analyzed and calories

| Constituents (g/100 g) | Nellore Sirloin | Wagyu Sirloin | Nellore Chuck | Wagyu Chuck |
|---|---|---|---|---|
| Moisture | 71.6 ± 0.9$^{a}$ | 51.6 ± 2.8$^{c}$ | 67.3 ± 1.2$^{b}$ | 49.4 ± 1.5$^{c}$ |
| Lipid | 5.8 ± 0.4$^{c}$ | 29.2 ± 2.3$^{a}$ | 9.8 ± 0.5$^{b}$ | 30.8 ± 1.6$^{a}$ |
| Ash | 1.0 ± 0.1$^{a}$ | 0.7 ± 0.0$^{c}$ | 0.9 ± 0.0$^{b}$ | 0.6 ± 0.0$^{c}$ |
| Protein | 21.7 ± 1.2$^{a}$ | 19.6 ± 1.5$^{b}$ | 22.1 ± 1.4$^{a}$ | 19.2 ± 1.5$^{b}$ |
| Calories (kcal/100 g) | 138.8 ± 4.9$^{c}$ | 341.1 ± 12.6$^{a}$ | 176.4 ± 6.0$^{b}$ | 354.1 ± 13.8$^{a}$ |

Means ± standard deviations of triplicate analyzes followed by the same letters in rows do not differ by Tukey test ($p > 0.05$).

## Results and Discussion

*Proximate chemical composition*

The proximate chemical composition of the beef samples analyzed and the calories are presented in Table 1. The initial moisture of Nellore cuts were higher than the Wagyu ones, thereat, it is possible to observe that Nellore beef showed lower lipid level, 5.8 g/100 g in sirloin steak and 9.8 g/100 g in chuck steak, than Wagyu, sirloin steak – 29.2 g/100 g, chuck steak – 30.8 g/100 g. This fact was due to the presence of intramuscular fat, marbling, not observed in Nellore beef. Sirloin steaks from Nellore heifers presented less lipid amount than found in this study, approximately 3.04 g/100 g of lipids, (Lage *et al*., 2012), possibly due to the sex, castrated bovines often contain higher fat content.

The ash percentage was significantly higher ($p \leq 0.05$) in the Nellore cuts (1.0 g/100 g, sirloin steak and 0.9 g/100 g, chuck steak) than in the Wagyu cuts (0.7 and 0.6 g/100 g, respectively). The ash percentage of Nellore cattle sirloin steak, in the standards of the United States Department of Agriculture (USDA), was 1.1 g/100 g, which is close to what found in the analyzed cuts (Smith *et al*., 2011).

Nellore cuts presented 21.7 g/100 g of protein in sirloin steak and 22.1 g/100 g in chuck steak, content significantly higher ($p \leq 0.05$) than those evidenced by Wagyu cuts, 19.6 and 19.2 g/100 g, respectively,

Table 2. Color features, cooking losses, and shear force of the beef samples analyzed

| Feature | Nellore Sirloin | Wagyu Sirloin | Nellore Chuck | Wagyu Chuck |
|---|---|---|---|---|
| Lightness (L*) | 36.8 ± 2.5$^{b}$ | 41.8 ± 2.3$^{a}$ | 41.5 ± 2.9$^{a}$ | 40.5 ± 2.9$^{a}$ |
| Redness (a*) | 20.3 ± 2.4$^{b}$ | 23.1 ± 2.5$^{ab}$ | 25.9 ± 4.4$^{a}$ | 24.9 ± 4.3$^{a}$ |
| Yellowness (b*) | 9.7 ± 1.4$^{c}$ | 11.9 ± 1.7$^{bc}$ | 14.4 ± 1.9$^{a}$ | 14.1 ± 2.5$^{ab}$ |
| Loss (%) | | | | |
| Evaporation | 22.2 ± 1.8$^{a}$ | 18.2 ± 1.4$^{bc}$ | 20.7 ± 1.8$^{ab}$ | 16.0 ± 2.2$^{c}$ |
| Drip | 3.3 ± 0.5$^{ab}$ | 2.9 ± 1.1$^{b}$ | 6.2 ± 2.4$^{a}$ | 3.5 ± 0.7$^{ab}$ |
| Total | 25.5 ± 1.6$^{a}$ | 21.1 ± 1.9$^{b}$ | 26.9 ± 2.0$^{a}$ | 19.5 ± 1.6$^{b}$ |
| Shear Force (N) | 45.9 ± 1.6$^{a}$ | 31.5 ± 0.9$^{bc}$ | 37.2 ± 0.7$^{b}$ | 25.8 ± 0.6$^{c}$ |

Means ± standard deviations of triplicate analyzes followed by the same letters in rows do not differ by Tukey test ($p > 0.05$).

this fact occurred due to its higher lipid contents. Cattle from the Spanish breeds "Parda de Montaña" (Serra *et al.*, 2008) and "Asturiana de la Montaña" (Sierra *et al.*, 2010) showed to be rich in proteins, with 21.7 and 22.4 g/100 g of this macronutrient, respectively, similar to those found in this work.

The energetic content provided by Wagyu or Kobe cuts, how they are designated, 341.1 kcal/100 g of sirloin steak and 354.1 kcal/100 g of chuck steak, is higher than the ones of Nellore, due to the fact that this one is richer in fat, which contributes with 9 kcal/g. According to Sizer and Whitney (2013), an adult, healthy person needs to consume 2,000 kcal/day. Therefore, the ingestion of 100 g of Wagyu sirloin steak provides 17% of the adequate daily energetic value, while, for the same cut of Nellore breed, this value decreases to 7%.

*Beef quality*

Table 2 presents the color characteristics, losses by cooking, and shear force of the analyzed beef samples. Concerning luminosity, the ability of the meat to reflect light, Wagyu sirloin steak, Nellore chuck steak, and Wagyu chuck steak did not present significant difference ($p > 0.05$). Only Nellore sirloin steak differed ($p \leq 0.05$), with $L^*$ content of 36.8. In a study performed by Jeong et al. (2011), with beef cuts from the Korean cattle breed Hanwoo, subjected to seven days of freezing, it was observed $L^*$ content of 39.7, which is close to what obtained in this study for Wagyu sirloin steak (41.8), Nellore chuck steak (41.5), and Wagyu chuck steak (40.5), in similar measurement conditions.

Red color intensity is a very important factor, which denotes beef health and, on that account, consumers decide to purchase the meat or not. It was observed that the chuck steak samples had more intense red color, and did not differ ($p > 0.05$) among each other, with values of 25.9 for Nellore breed and 24.9 for Wagyu. For Nellore sirloin steak, lower intensity was obtained, 20.3. Thus, this cut would possibly be the less attractive to consumer's choice.

The highest values found were close to the ones obtained by Sawyer *et al.* (2009) for *M. longissimus lumborum* muscle, during evaluation of pH influence, after rigor mortis resolution, on beef color. Coloration, in normal pH (5.4), was 26.9, and decreased to 22.9 with pH elevation (6.5). Nellore (14.4) and Wagyu (14.1) chuck steaks showed higher yellow color intensity, not differing statistically ($p > 0.05$) between each other, while the lowest intensity was presented by Nellore sirloin steak (9.7). The yellow color presented by Hanwoo Korean cattle sirloin steaks (12.7) was close to what presented by Wagyu sirloin steak (11.9), due to the *Bos taurus* genetics, which is common to both breeds (Cho *et al.*, 2010).

The losses by evaporation represent a reduction in the final moisture of the product after cooking; and they were higher in the Nellore cuts, with values of 22.2% in sirloin steak and 22.7% in chuck steak, not differing significantly between each other ($p > 0.05$). Although the Wagyu cuts had shown less susceptible to these losses, with percentages of 18.2 and 16, respectively, his final product will be drier than the Nellore ones, due to its lower initial moisture. In a study on the cooking losses in 15 different Nellore beef cuts, under dry and moist cooking, performed by Schönfeldt and Strydom (2011), sirloin steak, evaluated under dry cooking, showed 19.8% loss, close to the values obtained in this study.

In the loss by dripping, the "beef juice", that is composed by water, minerals, and other substances responsible for its flavor and aroma (Oillic *et al.*, 2011), is exuded. It is possible to infer that the losses by dripping cause, besides juiciness loss, a decrease of nutrient content. The most nutritious and attractive cut to human taste was Wagyu sirloin steak, for having presented lower loss by dripping, 2.9%; on the other hand, Nellore chuck steak showed 6.2%. In a comparative study on sirloin steaks from cattle fed with feed supplemented by linseed and vitamin E and with not supplemented feed, Juárez *et al.* (2012) obtained lower losses by dripping in animals fed with supplemented diet, 3.5%, contrasting with 4.1% presented by the sample resulting from not supplemented diet. The Wagyu chuck steak (3.5%) presented lower loss than what evidenced by sirloin

Table 3. Fatty acid composition and cholesterol content of the bovine fats analyzed

| | | Nellore Sirloin | Wagyu Sirloin | Nellore Chuck | Wagyu Chuck |
|---|---|---|---|---|---|
| Cholesterol (mg/kg) | | 436.2 ± 16.4$^{b}$ | 860.0 ± 4.8$^{a}$ | 377.1 ± 19.5$^{b}$ | 787.4 ± 2.5$^{a}$ |
| Fatty Acid (g fatty acid/100 g fat) | | | | | |
| Saturated | | 49.3 ± 5.9$^{a}$ | 45.5 ± 0.1$^{a}$ | 46.7 ± 4.0$^{a}$ | 38.3 ± 6.1$^{b}$ |
| Capric | C10:0 | nd | nd | 0.1 ± 0.0$^{a}$ | nd |
| Lauric | C12:0 | 0.1 ± 0.0$^{a}$ | 0.1 ± 0.0$^{a}$ | 0.1 ± 0.0$^{a}$ | 0.1 ± 0.0$^{a}$ |
| Myristic | C14:0 | 3.4 ± 0.1$^{a}$ | 3.3 ± 0.0$^{a}$ | 3.8 ± 0.1$^{a}$ | 2.4 ± 0.7$^{b}$ |
| Pentadecylic | C15:0 | 0.6 ± 0.2$^{a}$ | 0.3 ± 0.0$^{b}$ | 0.7 ± 0.3$^{a}$ | 0.3 ± 0.1$^{b}$ |
| Palmitc | C16:0 | 24.5 ± 1.9$^{a}$ | 26.9 ± 0.1$^{a}$ | 26.6 ± 1.6$^{a}$ | 26.4 ± 2.8$^{a}$ |
| Margaric | C17:0 | 1.1 ± 0.8$^{a}$ | 0.7 ± 0.0$^{a}$ | 0.7 ± 0.2$^{a}$ | 0.8 ± 0.1$^{a}$ |
| Stearic | C18:0 | 15.7 ± 4.8$^{a}$ | 11.5 ± 0.1$^{b}$ | 13.7 ± 2.8$^{ab}$ | 6.8 ± 2.6$^{c}$ |
| Arachidic | C20:0 | 0.3 ± 0.2$^{ab}$ | 0.2 ± 0.0$^{b}$ | 0.4 ± 0.2$^{a}$ | 0.2 ± 0.1$^{b}$ |
| Behenic | C22:0 | 0.5 ± 0.0$^{a}$ | 0.3 ± 0.0$^{b}$ | 0.2 ± 0.0$^{c}$ | 0.1 ± 0.0$^{c}$ |
| Lignoceric | C24:0 | 3.1 ± 0.5$^{a}$ | 2.3 ± 0.1$^{b}$ | 0.9 ± 0.3$^{c}$ | 1.3 ± 0.5$^{c}$ |
| Unsaturated | | 50.7 ± 6.1$^{c}$ | 54.5 ± 5.3$^{ab}$ | 53.3 ± 4.1$^{bc}$ | 61.7 ± 6.1$^{a}$ |
| Monounsaturated | | 48.5 ± 5.8$^{b}$ | 52.7 ± 0.1$^{b}$ | 50.1 ± 3.7$^{b}$ | 59.5 ± 6.2$^{a}$ |
| Myristoleic | C14:1 | 0.9 ± 0.2$^{a}$ | 0.7 ± 0.0$^{b}$ | 0.9 ± 0.3$^{a}$ | 0.6 ± 0.1$^{b}$ |
| Palmitoleic | C16:1 | 2.2 ± 0.7$^{c}$ | 4.0 ± 0.1$^{b}$ | 2.5 ± 0.4$^{c}$ | 4.6 ± 0.4$^{a}$ |
| Heptadecenoic | C17:1 | 1.9 ± 0.3$^{b}$ | 0.8 ± 0.0$^{c}$ | 2.5 ± 0.5$^{a}$ | 0.7 ± 0.1$^{c}$ |
| Oleic | C18:1 | 43.4 ± 4.9$^{b}$ | 47.3 ± 0.0$^{b}$ | 44.0 ± 3.0$^{b}$ | 53.5 ± 6.5$^{a}$ |
| Gondoic | C20:1 | 0.1 ± 0.0$^{b}$ | 0.1 ± 0.0$^{b}$ | 0.2 ± 0.0$^{a}$ | 0.1 ± 0.0$^{b}$ |
| Polyunsaturated | | 2.2 ± 0.4$^{b}$ | 1.6 ± 0.1$^{c}$ | 2.9 ± 0.4$^{a}$ | 2.2 ± 0.1$^{b}$ |
| Linoleic | C18:2 | 2.1 ± 0.3$^{b}$ | 1.5 ± 0.1$^{c}$ | 2.7 ± 0.4$^{a}$ | 1.9 ± 0.2$^{b}$ |
| α-linolenic | C18:3 | 0.1 ± 0.0$^{b}$ | nd | 0.10 ± 0.0$^{b}$ | 0.3 ± 0.0$^{a}$ |
| Saturated/Unsaturated | | 1.0 ± 0.3$^{a}$ | 0.8 ± 0.0$^{ab}$ | 0.9 ± 0.2$^{a}$ | 0.6 ± 0.2$^{b}$ |

Means ± standard deviations of triplicate analyses followed by the same letters in rows do not differ by Tukey test ($p > 0.05$).
nd: not detected.

steak obtained from supplemented diet.

Total losses by cooking were lower in Wagyu cuts and did not present significant difference ($p > 0.05$), with values of 21.1% in sirloin steak and 19.5% in chuck steak. Its lower dripping losses may contribute for the flavor of cooked meat, although the low initial water content will lead to a drier product. On the other hand, the Nellore cuts presented higher losses: sirloin steak – 25.5% and chuck steak – 26.9%, and also did not differ between each other ($p > 0.05$), presenting a more juicy, due to its initial moisture, and less flavorful final product. In a research developed by Yancey *et al.* (2011), Nellore sirloin steaks, purchased in local market, were subjected to cooking in conventional oven with forced air circulation, and presented 29.9% of losses; such value is superior to what shown by the samples analyzed in this study. Possibly, the higher desiccation was caused by air circulation, which may have enabled loss by evaporation.

The lower the shear force value, the higher the cut softness, and the easier the muscular fiber breaking during mastication. Among the analyzed samples, the softest was Wagyu chuck steak, with an unexpected result of 25.8 N, since it is a cut of secondary quality, with stiffer fibers. Marbling provides higher softness to beef, thus, Kobe cuts showed to be significantly softer than the ones from Nellore cattle. Nellore sirloin steak cut, evaluated by Warner *et al.* (2010), provided result similar to what found in this study for the same cut. The beef quality analyses realized suggests that Wagyu were the softest steaks, besides being the juiciest because of the lower cooking losses presented.

*Fat quality*

Table 3 shows the cholesterol content and the fatty acid composition of the bovine fats analyzed. It was observed that the cholesterol levels present in Wagyu cuts (860 mg/kg – sirloin steak and 787.4 mg/kg – chuck steak) were significantly higher ($p \leq 0.05$), representing approximately double the contents of Nellore cuts, 436.2 and 377.1 mg/kg, respectively. As expected, the cholesterol level did not vary significantly ($p > 0.05$) in the same breed. Sirloin steak from Wagyu cattle slaughtered after 20 months of confinement, studied by Chung *et al.* (2006), presented results that are compatible to that evidenced in this study for the correspondent cut, with 890 mg/kg of cholesterol.

All analyzed fats presented levels of saturated fatty acids that were lower than 50 g fatty acid/100 g fat. Wagyu chuck steak showed the lowest percentage of saturated, 38.3 g/100 g; the other cuts presented higher percentages and did not differ ($p > 0.05$) among each other. Palmitic acid stood out in all fats, with approximately 26% of the total fatty acids, in statistically similar percentages ($p > 0.05$). Stearic was the second most abundant acid, shown in higher quantity in Nellore sirloin steak fat (15.7 g/100 g) and in lower quantity in Wagyu chuck steak fat (6.8 g/100 g). Palmitic and stearic acids were also detected in higher quantity in the lipid fraction of Jersey calves, with levels of 25 and 11 g/100 g, respectively, similar to what obtained in the present study (Jiang *et al.*, 2013).

Wagyu chuck steak stood out regarding the level of unsaturated fatty acids, 61.7 g/100 g. On the other hand, Nellore sirloin steak presented the lowest amount, 50.7 g/100 g. Wagyu chuck steak fat was the richest in oleic acid, with 53.5 g/100 g, what confers better oxidative stability to the oil. Linoleic acid was detected in higher level in Nellore beef fats, 2.1 g/100 g in sirloin steak and 2.7 g/100 g in chuck steak.

Due to their human nutritional importance, it is pertinent to emphasize the great presence of the polyunsaturated fatty acid α-linolenic in Wagyu beefs (0.3 g/100 g), when compared to Nellore ones. Ludden et al. (2009) evaluated the fatty acid profile in intramuscular fat of Gelbvieh x Angus heifers and obtained results lower than those found in the studied fats as to the levels of linoleic (1.2 g/100 g) and α-linolenic (0.1 g/100 g) acids.

Although α-linolenic is an essential fatty acid, its presence in perceptible quantities affects beef flavor, producing off-flavor and off-aroma, thus transmitting fish or rancid taste and metallic or rank smell to the consumer. Therefore, the presence of this fatty acid is desirable in small quantities, from the sensorial point of view (Jiang *et al.*, 2011).

Aside from Nellore sirloin steak, which presented relation saturated/unsaturated fatty acids equals one, all the other samples showed relations lower than one, which means that they are unsaturated. Wagyu chuck steak fat stood out for being the most unsaturated, with value of 0.6.

Appreciating fat quality, both types of beef showed advantages and disadvantages. Nellore beefs presented the lowest levels of cholesterol, while Wagyu ones showed higher content of unsaturated fatty acids, and large amount of oleic acid, that reduces bloody levels of low density lipoprotein cholesterol LDLc and improves oil stability.

## Conclusion

This study permitted to conclude that the differences between the quality of beef and intramuscular fat of Nellore and Wagyu are caused mainly by their marbling degree, cholesterol content and fatty acid composition. Wagyu beefs stood out by their higher softness, due to their marbling degree, and by the higher unsaturated fatty acids content of their fats. The detrimental factor for Wagyu was the elevated cholesterol content, which represents harm to people's health. The softness, the marbling and the highest content of unsaturated fatty acids add value to the Wagyu cuts, making them gourmet products with selected target audience.

## Acknowledgements

The authors are grateful to the Beef Passion company for providing the samples and material support for the development of this study. And for the availability of the Laboratório de Qualidade e Certificação da Carne da Central Bela Vista, situated in the CRV Farm, Pardinho, São Paulo State, Brazil.

## References

AOAC. 2005. Official and tentative methods of the AOAC international. 18th edn. Maryland: AOAC International.

AOCS. 2009. Official methods and recommended practices of the American Oil Chemists Society. 6th edn. Illinois: AOCS Press.

Cho, S. H., Kim, J., Park, B. Y., Seong, P. N., Kang, G. H., Kim, J. H., Jung, S. G., Im, S. K. and Kim, D. H. 2010. Assessment of meat quality properties and development of a palatability prediction model for korean hanwoo steer beef. Meat Science 86(1): 236–242.

Chung, K. Y., Lunt, D. K., Choi, C. B., Chae, S. H., Rhoades, R. D., Adams, T. H., Booren, B. and Smith, S. B. 2006. Lipid characteristics of subcutaneous adipose tissue and *M. Longissimus thoracis* of angus and wagyu steers fed to us and japanese endpoints. Meat Science 73(3): 432–441.

Devine, C. 2014. Encyclopedia of meat sciences: 3-volume set. Amsterdam: Elsevier Science.

Duchateau, G. S. M. J. E., Bauer-Plank, C. G., Louter, A. J. H., van der Ham, M., Boerma, J. A., van Rooijen, J. J. M. and Zandbelt, P. A. 2002. Fast and accurate method for total 4-desmethyl sterol(s) content in spreads, fat-blends, and raw materials. Journal of the American Oil Chemists' Society 79(3): 273–278.

Ferraz, J. B. S. and Felício, P. E. d. 2010. Production systems – an example from brazil. Meat Science 84(2): 238–243.

Gotoh, T., Albrecht, E., Teuscher, F., Kawabata, K., Sakashita, K., Iwamoto, H. and Wegner, J. 2009. Differences in muscle and fat accretion in japanese black and european cattle. Meat Science 82(3): 300–308.

Jeong, J.-Y., Kim, G.-D., Yang, H.-S. and Joo, S.-T. 2011. Effect of freeze–thaw cycles on physicochemical properties and color stability of beef semimembranosus muscle. Food Research International 44(10): 3222–3228.

Jiang, T., Busboom, J. R., Nelson, M. L. and Mengarelli, R. 2011. Omega-3 fatty acids affected human perception of ground beef negatively. Meat Science 89(4): 390–399.

Jiang, T., Mueller, C. J., Busboom, J. R., Nelson, M. L., O'Fallon, J. and Tschida, G. 2013. Fatty acid composition of adipose tissue and muscle from jersey steers was affected by finishing diet and tissue location. Meat Science 93(2): 153–161.

Juárez, M., Dugan, M. E. R., Aldai, N., Basarab, J. A., Baron, V. S., McAllister, T. A. and Aalhus, J. L. 2012. Beef quality attributes as affected by increasing the intramuscular levels of vitamin e and omega-3 fatty acids. Meat Science 90(3): 764–769.

Lage, J. F., Paulino, P. V. R., Filho, S. C. V., Souza, E. J. O., Duarte, M. S., Benedeti, P. D. B., Souza, N. K. P. and Cox, R. B. 2012. Influence of genetic type and level of concentrate in the finishing diet on carcass and meat quality traits in beef heifers Meat Science 90(3): 770–774.

Ludden, P. A., Kucuk, O., Rule, D. C. and Hess, B. W. 2009. Growth and carcass fatty acid composition of beef steers fed soybean oil for increasing duration before slaughter. Meat Science. 82(2): 185–192.

Merrill, A. L. and Watt, B. K. 1973. Energy value of foods: Basis and derivation. Washington: Human Nutrition Research Branch, Agricultural Research Service.

Morales, R., Aguiar, A. P. S., Subiabre, I. and Realini, C. E. 2013. Beef acceptability and consumer expectations associated with production systems and marbling. Food Quality and Preference 29(2): 166–173.

Oillic, S., Lemoine, E., Gros, J.-B. and Kondjoyan, A. 2011. Kinetic analysis of cooking losses from beef and other animal muscles heated in a water bath — effect of sample dimensions and prior freezing and ageing. Meat Science 88(3): 338–346.

Okumura, T., Saito, K., Sowa, T., Sakuma, H., Ohhashi, F., Tameoka, N., Hirayama, M., Nakayama, S., Sato, S., Gogami, T., Akaida, M., Kobayashi, E., Konishi, K., Yamada, S. and Kawamura, T. 2012. Changes in beef sensory traits as somatic-cell-cloned japanese black steers increased in age from 20 to 30 months. Meat Science 90(1):159–163.

RIISPOA. 1980. Regulamento da inspeção industrial e sanitária dos produtos de origem animal. Brasil: Ministério da Agricultura.

Rossato, L. V., Bressan, M. C., Rodrigues, É. C., Carolino, M. I. A. d. C. M., Bessa, R. J. B. and Alves, S. P. P. 2009. Composição lipídica de carne bovina de grupos genéticos taurinos e zebuínos terminados em confinamento. Revista Brasileira de Zootecnia 38(9): 1841–1846.

Sawyer, J. T., Apple, J. K., Johnson, Z. B., Baublits, R. T. and Yancey, J. W. S. 2009. Fresh and cooked color of dark-cutting beef can be altered by post-rigor enhancement with lactic acid. Meat Science 83(2): 263–270.

Schönfeldt, H. C. and Strydom, P. E. 2011. Effect of age and cut on cooking loss, juiciness and flavour of south african beef. Meat Science 87(3): 180–190.

Serra, X., Guerrero, L., Guàrdia, M. D., Gil, M., Sañudo, C., Panea, B., Campo, M. M., Olleta, J. L., García-Cachán, M. D., Piedrafita, J. and Oliver, M. A. 2008. Eating quality of young bulls from three spanish beef breed-production systems and its relationships with chemical and instrumental meat quality. Meat Science 79(1): 98–104.

Sierra, V., Guerrero, L., Fernández-Suárez, V., Martínez, A., Castro, P., Osoro, K., Rodríguez-Colunga, M. J., Coto-Montes, A. and Oliván, M. 2010. Eating quality of beef from biotypes included in the PGI "Ternera Asturiana" showing distinct physicochemical characteristics and tenderization pattern. Meat Science 86(2): 343–351.

Silva, S. L., Leme, P. R., Putrino, S. M., Pereira, A. S. C., Valinote, A. C., Nogueria Filho, J. C. M. and Lanna, D. P. D. 2009. Fatty acid composition of intramuscular fat from nellore steers fed dry or high moisture corn and calcium salts of fatty acids. Livestock Science 122(2–3): 290–295.

Sizer, F. and Whitney, E. 2013. Nutrition: Concepts and controversies. Connecticut: Cengage Learning.

Smith, A. M., Harris, K. B., Haneklaus, A. N. and Savell, J. W. 2011. Proximate composition and energy content of beef steaks as influenced by usda quality grade and degree of doneness. Meat Science 89(2): 228–232.

Warner, R. D., Greenwood, P. L., Pethick, D. W. and Ferguson, D. M. 2010. Genetic and environmental effects on meat quality. Meat Science 86(1): 171–183.

Yancey, J. W. S., Wharton, M. D. and Apple, J. K. 2011. Cookery method and end-point temperature can affect the warner–bratzler shear force, cooking loss, and internal cooked color of beef longissimus steaks. Meat Science 88(1): 1–7.