

## Impact of frozen temperature and thawing methods on the Brazilian sensory profile of Nellore beef

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Edited by: Luís Guilherme de Lima Ferreira Guido

Received March 16, 2020

Accepted June 24, 2020

**ABSTRACT:** We evaluated the effect of frozen storage temperature and thawing methods on acceptance and sensory profile of steaks of Nellore beef strip loin under 30 days of frozen storage. Fresh strip loin (n = 13), collected two days after slaughter, were aged (2 °C) for 14 days and cut into seven steaks subjected to one of the treatments: control (unfrozen), combination of two freezing temperatures (-10 and -20 °C), and three thawing methods (microwave, ambient temperature, and refrigeration thawing). Steaks in the frozen/thawing treatment were frozen using an ultra-fast freezer until the desirable temperature was reached and were stored for 30 days. After cooking, steaks were analyzed by 11 panelists for the Quantitative Descriptive Analysis (QDA<sup>®</sup>) and by 120 beef consumers for acceptance. Storage temperature and thawing methods showed little or no changes in the sensory quality of strip loin steaks, detected by either panelists or consumers. In the QDA<sup>®</sup>, apparent juiciness was lower in samples thawed in microwave, while the rancid flavor was lower for samples frozen at -20 °C and thawed in refrigeration (p < 0.05). The consumer test showed that samples stored at -10 °C and microwave thawing was most accepted in terms of tenderness, juiciness, and overall impression. Fresh steaks (unfrozen) had low acceptance for overall impression in relation to frozen meat. This indicates that consumers could use a household freezer (-10 °C) and quicker thawing methods (microwave or room temperature) without compromising the sensory perception of steaks frozen up to one month.

**Keywords:** strip loin steaks, quantitative descriptive analysis, acceptance test, freezing temperature

### Introduction

Frozen storage is a preservation method widely used for perishable food products, such as meat. Industries and retail stores normally operate with temperatures below -20 °C, while domestic freezers operate near -10 °C (Huang et al., 2013). Nevertheless, freezing could reduce meat quality, leading consumers to prefer unfrozen and thawed meat (Lagersted et al., 2008; Coombs et al., 2017).

Thawing is used to restore the original food quality as much as possible and is crucial (Leygonie et al., 2012). The influence of thawing on meat quality is determined by temperature, time, and methods (Kondratowicz et al., 2006). Inappropriate thawing may compromise meat quality, especially texture, flavor, and color (Benjakul et al., 2003).

Refrigeration (4 °C) is the most cited thawing method for meat in scientific studies (Kim et al., 2013; Skorpilová et al., 2014; Aroeira et al., 2016). However, it is considered a slow method and has not yet been compared with other methods for its effects on the sensory quality of beef. There is lack of information for consumers about the suitable frozen storage temperature and thawing methods, fast or slow, which avoid undesirable sensory changes.

Current studies report the effects of freezing (Kim et al., 2015; Lagerstedt et al., 2008; Muela et al., 2010, 2012), thawing (Manios and Skandamis, 2015) and frozen storage time (Huang et al., 2013; Muela et al.,

2015) on meat quality. However, little is reported on the combined effects of freezing, thawing, and freezing time.

Studies have shown that frozen storage temperatures or thawing methods could lead to the formation of ice crystals, affecting physicochemical and sensory characteristics of meat (Carlucci et al., 1999; Lagersted, 2008; Vieira et al., 2009; Bueno et al., 2013; Huang et al., 2013). Most studies on the sensory analysis of meat freezing have focused on meat flavor and texture (Zhang et al., 2019; Ji et al., 2019); however, no studies have used the Quantitative Descriptive Analysis (QDA<sup>®</sup>) to describe the effects of freezing/thawing processes on sensory attributes of meat, such as appearance, aroma, flavor, and texture for a comprehensive sensory assessment.

Behaviors, expectations, and needs of consumers have changed over the years, leading to the search for practical and fast-preparing methods. In this context, this study investigated the descriptive sensory profile and consumer acceptance of cooked strip loin steaks of Nellore beef subjected to different frozen storage temperatures (-10 and -20 °C) and thawed by three different methods (microwave, ambient temperature, and refrigeration).

### Materials and Methods

The research was approved by the Ethics Committee of the University of Campinas (Protocol Number: 55679116.0.0000.5404) and all volunteers provided a written consent.

### Sampling

We collected strip loins ( $n = 13$ ) (*M. longissimus lumborum*) with the same fat thickness (3 to 5 mm thick, measured between the 12<sup>th</sup> and 13<sup>th</sup> ribs, "practically devoid" of marbling), from grass fed Nellore steers (around 30 months old; 300 kg  $\pm$  24 kg average carcass weight), directly from a commercial slaughterhouse from the state of São Paulo, Brazil. After collection, the samples were vacuum packed, placed in isothermal boxes, and transported to the laboratory. The strip loins were aged for 14 days (2 °C). Afterward, each piece was cut into seven steaks (perpendicular to steak surface) 2.54 cm thick. The steaks were assigned randomly to one of the seven treatments: one steak was assigned as fresh meat (Control/Unfrozen), and the other six steaks to the factorial scheme (2  $\times$  3) at two freezing temperatures of -10 °C and -20 °C, and three thawing methods of 20 °C, 4 °C, and microwave thawing. Fresh (unfrozen) steaks were subjected immediately to the sensory analysis (120 consumers and 11 trained panelists), while steaks in the remaining treatments were frozen at the correspondent temperature for 30 days before thawing and the analysis (other 120 consumers and the same 11 trained panelists).

### Control samples

Control beef steaks (unfrozen) were individually vacuum packed, kept at 4 °C in a refrigeration chamber during the analyses, carried out on the same day.

### Frozen samples

The beef steaks for freezing were individually vacuum packed. Steaks were subjected to rapid freezing in an ultra-fast freezer (Easy Fresh Fast Freezer EF30.1, 90) until the desirable temperature. The temperature was controlled by a copper/constantan thermocouple inserted into the center of one steak from each treatment.

When the desirable temperature (-10 °C and -20 °C) was reached, the frozen steaks were stored in the freezer at controlled temperature for 30 days.

### Thawing methods

In all treatments, the steaks were thawed when the internal temperature of the samples reached 4 °C. The thawing methods comprised: ambient temperature thawing (AT, 20 °C, approximately 4 h) (incubator chamber Eletrolab, EL 101/3; -6/+60 °C); refrigerator thawing (RT, 4 °C, approximately 12 h) (127V, MAGE, GE, automatic thawing); and microwave thawing (MT, 1 min, turn over the steak, 1 min. The process was repeated until 4 °C was reached, totaling approximately 4 min), regulated to 800 W (Brastemp, BMX40, 38 L). All thawed steaks were placed in a refrigeration chamber at 4 °C for 1 h before the analysis.

### Cooking method

The procedures for cooking the steaks for sensory evaluation were based on a modified experimental protocol described by the American Meat Science Association (AMSA, 2015). After thawing, beef steaks

were cooked in a conventional electric oven, preheated for 30 min at the high setting and adjusted to 170 °C. After the internal temperature reached its halfway point (35.5 °C), the steaks were turned over and remained in this position until reaching the final temperature (71 °C). The internal temperature was monitored by copper/constantan thermocouples inserted into the geometric center of each steak connected to a digital temperature indicator.

After cooking, the steaks were cut into 1.5  $\times$  1.5 cm cubes, placed in glass containers, and kept in a yogurt maker at approximately 40 °C for the sensory analysis with panelists and consumers.

### Sensory evaluation

The Quantitative Descriptive Analysis (QDA®) and the consumer acceptance test were conducted by panelists.

For both sensory tests, the analysis was performed in individual booths with controlled temperature (22 °C) and white light. The steaks, one from each frozen/thawing treatment, were distributed according to a balanced complete block design, alternating the position across treatments to minimize the effect of steak position (MacFie et al., 1989). Samples were served in a ramekin labeled with three-digit numbers, and participants were instructed to rinse the mouth with water between tests to avoid the carry-over effect.

Control beef steaks (unfrozen) were evaluated for QDA® and consumer acceptance separately from frozen/thawed samples, since they could not be frozen. The first sensory analysis was carried out with the control samples in order to eliminate possible interferences of freezing and thawing.

### QDA®

The descriptive profile of beef steaks was determined according to the Quantitative Descriptive Analysis (QDA®), as proposed by Stone et al. (2012).

### Selection of panelists

Panelists were selected through the Wald sequential analysis (Meilgaard et al., 2007). Two beef steak samples were prepared to have a significant difference at 0.1 % level in relation to sample texture. Triangular difference tests were applied to beef consumers. Thirteen assessors aged 18-25 years were pre-selected, all non-smokers, and willing to participate in the sensory evaluation.

### Development of descriptive terminology

The Kelly Repertory Grid Method (Moskowitz, 1983) was used to determine descriptors of cooked beef strip loin samples. Samples were presented in pairs and each panelist described similarities and differences of each pair regarding appearance, aroma, flavor, and texture. After a discussion with team members, the most appropriate and important descriptors were selected. Sixteen descriptors were developed, as well as their definitions and references (Table 1).

**Table 1** – Descriptors and references used for the sensory profiling of beef strip loin.

Attributes	Definition	References
Internal brown color	Internal brown color intensity	Weak: 7.5 YR 7/4/ volume 1 (Munsell, 1976). Strong: 5 YR 4/4/ volume 1 (Munsell, 1976).
Doneness degree	Intensity of internal color ranging from little to very cooked	Less cooked: Beef steak color guide (AMSA, 1995). Very cooked: Beef steak color guide (AMSA, 1995).
Apparent juiciness	Release of liquid ranging from dry appearance to a visible amount of liquid separated from beef	Less: beef inside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C). Very: beef tenderloin (0.025 m) roasted in electric oven (60 °C).
Crumbling	Presence of fibers	Less: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Very: beef (0.025 m) matured for 14 days.
Roast beef aroma	Intensity of roast beef aroma	Weak: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef inside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C).
Boiled beef aroma	Intensity of boiled beef aroma	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef shank (0.025 m) boiled in pressure cooker for 30 min.
Metallic aroma	Intensity of odor metal/iron flavor	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef inside round (0.04 × 0.04 × 0.025 m) soaked in solution of ferrous sulfate (0.5 %) for 2 h, roasted in electric oven (71 °C).
Rancid aroma	Odor associated with rancid meat	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: Desalted dry meat.
Roast beef flavor	Intensity of roast beef flavor	Weak: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef inside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C).
Boiled beef flavor	Intensity of boiled beef flavor	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef shank (0.025 m) boiled in pressure cooker for 30 min.
Metallic flavor	Intensity of metal/iron flavor	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: beef inside round (0.04 × 0.04 × 0.025 m) soaked in solution of ferrous sulfate (0.5 %) for 2 h, roasted in electric oven (71 °C).
Rancid flavor	Flavor associated with rancid meat	None: beef inside round (0.04 × 0.04 × 0.025 m) soaked in water for 12 h, roasted in electric oven (71 °C). Strong: Desalted dry meat.
Initial tenderness	Minimum force necessary (first bite) to bite the meat sample with incisors teeth	Less: beef outside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C). Very: beef tenderloin (0.025 m) roasted in electric oven (60 °C).
Initial juiciness	Amount of liquid released during chewing with the molar teeth	Less: beef outside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C). Very: beef tenderloin (0.025 m) roasted in electric oven (60 °C).
Chewiness	Time and strength (energy) required to chew the sample with the molars until swallowing	Less: beef tenderloin (0.025 m) roasted in electric oven (60 °C). Very: beef outside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C).
Fibrosity	Fibers perceived during mastication	Less: beef tenderloin (0.025 m) roasted in electric oven (60 °C). Very: beef outside round (0.04 × 0.04 × 0.025 m) roasted in electric oven (75 °C).

### Training sessions and selection of panelists

The panelists were trained for the formation of sensory memory and equalization with maximum and minimum intensity references for each attribute. Nine training sessions of 2 h duration were conducted. The analyses were performed over a 7-day period and each sample (and each repetition) was evaluated for 15 min (Damasio and Costell, 1991).

### Quantitative descriptive analysis

During the training period, two panelists gave up the test; therefore, the quantitative descriptive analysis was carried out with 11 panelists. The selected panelists evaluated the samples in six replicates in a monadic design and according to a complete balanced block design. A

separate sensory analysis was performed to evaluate the control samples, with the same panelists (MacFie et al., 1989). Each panelist received an assessment form and was invited to evaluate the intensity of each attribute using a 10 cm (unstructured) linear scale, anchored at the extremities by "weak", "less", or "none" to the left, and "strong" and "very" to the right (Meilgaard et al., 2007).

### Acceptance test

One hundred and twenty beef consumers were recruited to participate in the acceptance test for fresh samples and, afterward, (after 30 days of freezing) other 120 consumers were recruited to participate to test frozen/thawed samples. All participants were adults

over 18 years of age who consumed beef at least once a week. In both tests, the age of consumers ranged from 18 to 45 years, with 55 % women and 45 % men.

Each consumer received six samples, one from each frozen × thawing treatment, in a monadic design and a complete balanced block design (MacFie et al., 1989). The control treatment (unfrozen) was previously assessed by consumers. Consumers were asked to evaluate meat acceptance in terms of appearance, aroma, flavor, tenderness, juiciness, and overall impression, using a 9-cm unstructured hedonic scale anchored with the terms "disliked very much" and "liked very much" (Stone et al., 2012).

Consumers could not be the same to test fresh and frozen samples, because it is not possible to guarantee the same type of samples (animal characteristics) on different slaughter days in the Brazilian slaughter system. However, when choosing the participants in an acceptance test, the important thing is to select a representative group of consumers, ensuring that they are all "likers", that is, that they "like it very much" and are regular consumers of the product under study (Meilgaard et al., 2015).

Each assessor was previously oriented regarding the attributes of tenderness and juiciness.

### Statistical analysis

The training of assessors was validated for each descriptive term using the ANOVA. In particular, we evaluated their ability to discriminate ( $p < 0.50$ ), repeatability of the assessor ( $p > 0.05$ ), and inter-taster agreement (Damásio and Costell, 1991). Data related to consumer acceptability and QDA<sup>®</sup> were analyzed by the two-way ANOVA, with two variation sources (assessor and sample). For both analyses, means were compared

by the Tukey test when a significant difference ( $p < 0.05$ ) was detected for any variable between samples (Gomes et al., 2014). The results were analyzed using the SAS software – Statistical Analysis Software v. 9.4, 2012 (SAS Institute Inc., North Carolina, USA). The QDA<sup>®</sup> datasets were arranged in a matrix of *i* lines (samples) and *j* columns (attributes), and the principal component analysis (PCA) was carried out (Alencar et al., 2017). The Hierarchical Cluster Analysis (HCA) was also performed with QDA<sup>®</sup> samples considering the Euclidian distances (dissimilar) and Ward techniques (agglomeration method) and automatic truncation (Moussaoui and Varela, 2010). The External Preference Map was also drafted to analyze the descriptive and affective data generated in this study (Gomes et al., 2014), performed with XLSTAT (version 2007. 7. Paris, France: Addinsoft SARL).

## Results and Discussion

### Quantitative descriptive analysis

The sensory analysis showed that frozen storage temperatures and thawing methods did not cause any negative effects to most attributes, when compared to control samples (unfrozen). Only two out of 16 sensory attributes (apparent juiciness and rancid flavor) were significantly affected by the treatments. The mean values of the sensory evaluation regarding appearance, aroma, flavor, and texture of the samples of seven treatments are shown in Table 2.

Appearance attributes, namely internal brown color, doneness degree, and crumbling, showed no significant differences ( $p > 0.05$ ) in all treatments. Conversely, higher scores ( $p < 0.05$ ) were observed for apparent juiciness of control beef steaks, as well as beef steaks stored at  $-10\text{ }^{\circ}\text{C}$  and subjected to thawing in

**Table 2** – Mean of descriptive attributes according to the quantitative descriptive analysis (QDA<sup>®</sup>), evaluated by 11 panelists.

Descriptor	Frozen Storage		-10 (°C)			-20 (°C)			Control Fresh meat
	Thawing Methods		MT (800 W)	AT (20 °C)	RT (4 °C)	MT (800 W)	AT (20 °C)	RT (4 °C)	
Appearance	Internal brown color		5.56	5.36	5.45	5.20	5.01	5.84	5.20
	Degree of doneness		6.13	5.40	5.60	6.13	5.67	5.94	6.39
	Apparent juiciness		2.70 <sup>c</sup>	5.02 <sup>a</sup>	5.36 <sup>a</sup>	3.13 <sup>bc</sup>	4.15 <sup>ab</sup>	4.43 <sup>a</sup>	5.05 <sup>a</sup>
	Crumbling		1.43	1.04	1.13	1.53	1.26	0.92	1.48
Aroma	Roast beef		4.94	4.36	5.06	5.50	5.37	5.08	5.36
	Boiled beef		2.95	3.26	3.04	3.29	2.83	3.19	2.57
	Metallic		1.60	2.29	2.56	1.70	2.15	1.80	2.43
	Rancid		0.65	0.49	0.74	0.52	0.59	0.46	0.33
Flavor	Roast beef		5.30	5.15	5.60	5.12	5.61	5.64	5.35
	Boiled beef		2.92	2.86	2.63	2.99	3.12	2.88	2.21
	Metallic		2.07	2.40	2.72	2.00	2.07	1.90	1.96
	Rancid		0.82 <sup>a</sup>	0.51 <sup>ab</sup>	0.78 <sup>a</sup>	0.70 <sup>a</sup>	0.83 <sup>a</sup>	0.16 <sup>b</sup>	0.57 <sup>ab</sup>
Texture	Initial tenderness		5.86	5.75	6.11	4.90	5.43	5.84	4.98
	Initial Juiciness		4.02	4.96	5.17	3.78	4.86	4.51	3.84
	Chewiness		3.67	3.23	3.53	4.13	4.06	3.36	4.40
	Fibrosity		3.61	2.81	3.12	3.57	3.53	3.40	4.45

<sup>a,b</sup>Means in the same row with different superscript letters differ significantly ( $p < 0.05$ ) by Tukey test. FM = Fresh meat; RT = refrigerator thawing; AT = ambient temperature thawing; MT = microwave thawing. Linear scale (10 cm unstructured), from "weak", "less", or "none" to "strong" and "very".



refrigeration or at room temperatures, as well as for beef steaks stored at  $-20\text{ }^{\circ}\text{C}$  subjected to refrigeration thawing, when comparing with samples thawed in microwave at both freezing temperatures ( $-10\text{ }^{\circ}\text{C}$  and  $-20\text{ }^{\circ}\text{C}$ ).

Taher and Farid (2001) reported that the microwave thawing process in meat occurs slowly from surface to the inner part the sample, which may explain why panelists characterized the samples thawed in the microwave with less apparent juiciness than in the other treatments. However, other studies report that microwave-thawed meat presents better sensory properties regarding texture than meat thawed in refrigeration or in room temperature. Microwave thawing is the most appropriate method (Kim et al., 2013; Ku et al., 2014), as it promotes better flavor and juiciness characteristics (Augusty-ska-Prejsnar et al., 2019).

No significant differences ( $p > 0.05$ ) were observed between treatments for aroma sensory attributes (roast beef, boiled beef, metallic, and rancid). Metallic and rancid aromas, main cause of sensory meat rejection, were below the middle of the 10-cm scale, indicating low intensity. According to Vieira et al. (2009), the panelists did not detect rancid odor in unfrozen steaks and in steaks frozen for 30 days at temperatures  $-20$  and  $-80\text{ }^{\circ}\text{C}$ , thawed for 48 h at  $4\text{ }^{\circ}\text{C}$ . Similarly, Choi et al. (2018) did not detect signs of lipid oxidation in lamb meat after thawing, when assessed by trained panelists. For Ali et al. (2015), the main factor that results in lipid and protein oxidation is the process of various freeze-thaw cycles.

Flavor sensory attributes (roast beef, boiled beef, and metallic flavor) had no significant differences ( $p > 0.05$ ) between treatments. Regarding the rancid flavor, samples stored at  $-10$  and  $-20\text{ }^{\circ}\text{C}$  and subjected to microwave thawing, refrigeration thawing at  $-10\text{ }^{\circ}\text{C}$ , and room temperature thawing at  $-20\text{ }^{\circ}\text{C}$  showed significantly higher ( $p < 0.05$ ) scores than samples stored at  $-20\text{ }^{\circ}\text{C}$  and subjected to refrigeration thawing. However, no significant changes were observed to samples stored at  $-10\text{ }^{\circ}\text{C}$  and subjected to room temperature thawing and to unfrozen steaks. Although the panelists found differences between the samples for rancid flavor, averages were low (below 1) in relation to the scale used 10 cm (unstructured) linear scale.

Vieira et al. (2009) found no significant differences ( $p > 0.05$ ) for flavor intensity in unfrozen steaks and 30-day frozen steaks at temperatures  $-20$  and  $-80\text{ }^{\circ}\text{C}$ , thawed for 48 h at  $4\text{ }^{\circ}\text{C}$ . According to Lagersted et al. (2008), for panelists, chilled meat showed higher intensity of meat taste compared to frozen meat submitted to temperature  $-20\text{ }^{\circ}\text{C}$  and thawed in room temperature.

Regarding texture attributes, no significant differences ( $p > 0.05$ ) were observed for initial tenderness, initial juiciness, chewiness, and fibrosity between the treatments. Hildrum et al. (1999) reported similar results. The authors studied fast freezing ( $-40\text{ }^{\circ}\text{C}$ ) of steaks, followed by slow thawing (2 d at  $4\text{ }^{\circ}\text{C}$ ), and found no difference in tenderness when compared to unfrozen samples. The same authors reported, however,

less juiciness in the samples subjected to freezing. However, Lagersted et al. (2008) found different results and reported that panelists found lower tenderness for frozen/thawed beef steaks when compared to refrigerated meat. According to Beltrán and Bellés (2019), frozen storage and thawing modify muscle structure, due to ice crystals formation. Nevertheless, in this study, fresh and frozen meats did not present significant differences each other ( $p > 0.05$ ), meaning that ice crystals formation possibly do not influence acceptance.

The PCA (Figure 1) allows the comparison between sensory characteristics of frozen steaks. The principal components I and II explained 63.6 % of the sample variation. Beef steaks stored at  $-10\text{ }^{\circ}\text{C}$  and subjected to refrigeration thawing were characterized mainly by initial juiciness, while steaks stored at  $-20\text{ }^{\circ}\text{C}$  and thawed in room temperature were characterized by rancid flavor.

According to the Hierarchical Cluster Analysis (HCA) (Figure 2), samples from QDA<sup>®</sup> analysis were grouped into four clusters. Frozen steaks ( $-10\text{ }^{\circ}\text{C}$  and  $-20\text{ }^{\circ}\text{C}$ ), thawed in microwave, remained in the same cluster. Steaks frozen at  $-10$  and  $-20\text{ }^{\circ}\text{C}$  thawed in room temperature and steaks frozen at  $-20\text{ }^{\circ}\text{C}$  thawed in refrigeration, remained in the same cluster. Steaks frozen at  $-10\text{ }^{\circ}\text{C}$  and thawed in refrigeration and unfrozen steaks remained isolated in groups of different clusters.

The HCA suggests that panelists reported differences between the samples that did not undergo the freezing/thawing process compared to the samples that were submitted to the processes studied. Samples frozen at  $-10$  and  $-20\text{ }^{\circ}\text{C}$  thawed in microwave were grouped in the same cluster, indicating that panelists did not detect differences between the samples. The same occurred for samples frozen at  $-10$  and  $-20\text{ }^{\circ}\text{C}$  in room temperature and at  $-20\text{ }^{\circ}\text{C}$  in refrigeration.

### Acceptance test

The results of the acceptance test by consumers are shown in Table 3. For the six parameters evaluated by consumers, averages were above the middle of the 9-cm hedonic scale, indicating good acceptance by consumers. According to Muñoz et al. (1992), an acceptance index of 6.0 on a 9-point hedonic scale is considered as a commercial and quality threshold.

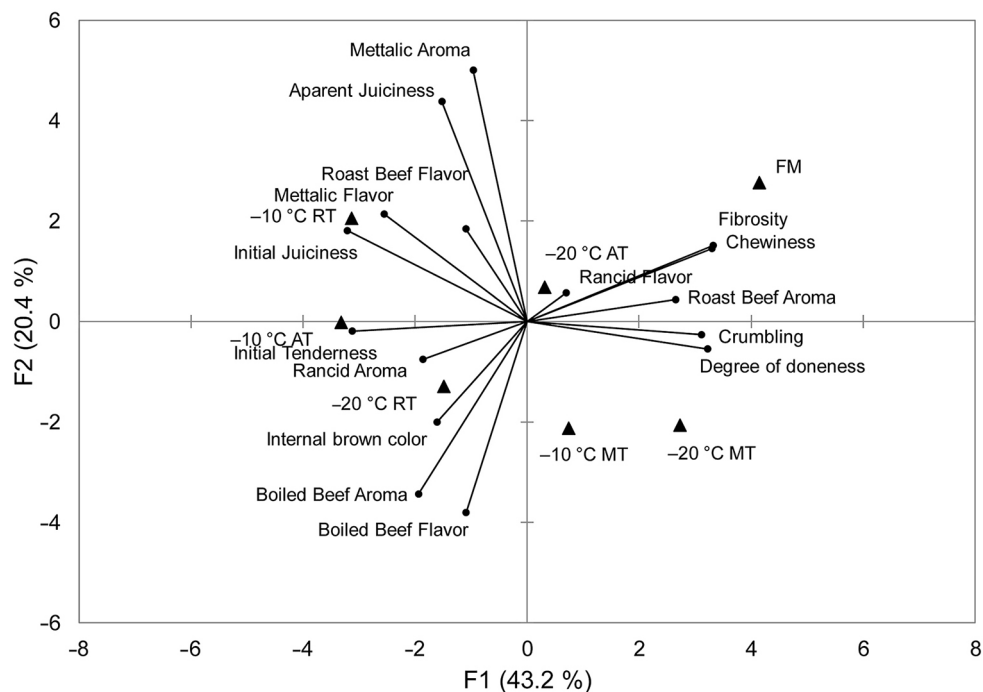
Appearance of cooked samples, subjected to the freezing process followed by thawing, was more accepted ( $p < 0.05$ ) by consumers than appearance of cooked steaks not subjected to freezing. On the other hand, storage temperature ( $-10$  and  $-20\text{ }^{\circ}\text{C}$ ) and thawing methods did not change appearance of the cooked beef steaks ( $p > 0.05$ ), according to evaluations by consumers.

For aroma and flavor, consumers found no significant differences ( $p > 0.05$ ) between the samples subjected to different freezing/thawing treatments and unfrozen samples, suggesting that these samples were sufficiently accepted by consumers. This may be associated to the fact that meat from Nellore animals,

**Table 3** – Means of attributes evaluated in the acceptance testing, evaluated by 120 consumers.

Frozen Storage Temperature	-10 (°C)			-20 (°C)			Control FM
	MT (800 W)	AT (20 °C)	RT (4 °C)	MT (800 W)	AT (20 °C)	RT (4 °C)	
Appearance	6.31 <sup>a</sup>	6.30 <sup>a</sup>	6.25 <sup>a</sup>	6.25 <sup>a</sup>	6.30 <sup>a</sup>	6.37 <sup>a</sup>	5.37 <sup>b</sup>
Aroma	6.04	5.96	6.07	6.12	5.87	6.07	5.50
Flavor	6.61	6.21	6.26	6.29	6.32	6.39	6.18
Tenderness	6.76 <sup>a</sup>	6.10 <sup>ab</sup>	6.11 <sup>ab</sup>	6.33 <sup>ab</sup>	6.21 <sup>ab</sup>	6.44 <sup>ab</sup>	5.72 <sup>b</sup>
Juiciness	6.54 <sup>a</sup>	6.11 <sup>ab</sup>	5.99 <sup>ab</sup>	6.08 <sup>ab</sup>	5.86 <sup>ab</sup>	6.21 <sup>ab</sup>	5.52 <sup>b</sup>
Overall impression	6.68 <sup>a</sup>	6.34 <sup>ab</sup>	6.23 <sup>ab</sup>	6.44 <sup>ab</sup>	6.20 <sup>ab</sup>	6.52 <sup>ab</sup>	5.95 <sup>b</sup>

<sup>ab</sup>Means with common letters in the same row indicate no significant difference between samples ( $p \leq 0.05$ ) by Tukey test. MT = microwave thawing; AT = ambient temperature thawing (20 °C); RT = refrigerator thawing (4 °C); FM = fresh meat. 9-cm unstructured hedonic scale anchored with the terms "disliked very much" and "liked very much".



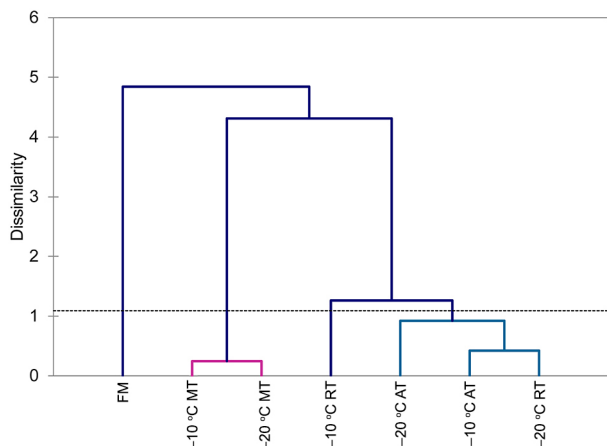
**Figure 1** – Principal Components Analysis loading plot as defined by PCA 1 (43.2 %) and PCA 2 (20.4 %) for sensory beef quality traits on panel test analysis. Triangle = treatments; FM = Fresh meat; RT = refrigerator thawing; AT = ambient temperature thawing; MT = microwave thawing. -10 and -20 °C: frozen storage temperatures.

finished in pasture systems, has lower intramuscular fat, which reduces its flavor intensity, without affecting beef acceptance after freezing. According to Fernandes et al. (2013), consumers found no significant difference for aroma and flavor in lamb meat samples frozen at -18 °C and thawed in refrigeration when compared to unfrozen samples. However, frozen storage for long periods may cause undesirable changes in flavor intensity (Daszkiewicz et al., 2018).

Overall, acceptance scores for tenderness and juiciness increased with the freezing process followed by thawing, when compared to unfrozen samples. Samples stored at -10 °C and subjected to microwave thawing had higher scores for tenderness and juiciness (6.75 and 6.54, respectively); while samples stored at -10 °C and subjected to thawing in room temperature

or refrigeration had lower scores for tenderness (6.10 and 6.11, respectively). Samples stored at -20 °C and thawed in room temperature were considered less juicy (5.86); nevertheless, no statistical differences were observed. Meat tenderness and juiciness result from a combination of intrinsic (amount of collagen, amount of fats, denaturation of myofibrillar proteins, and water loss) and extrinsic (temperature and length of cooking) factors (Juárez et al., 2011). The fat content shows a positive correlation with tenderness and juiciness of meat due to the lubrication provided (Bruns et al., 2004), increasing perception of attributes, such as greater palatability and tenderness (Silva and Cadavez, 2012).

The highest scores for overall impression were reported in samples stored at -10 °C and subjected to microwave thawing (6.67), and in samples stored at



**Figure 2** – Dendrogram obtained from Hierarchical Clustering Analysis (HCA) of QDA. Four clusters were formed. Group 1: microwave thawing (MT) stored at  $-10^{\circ}\text{C}/-20^{\circ}\text{C}$ ; Group 2: ambient temperature thawing (AT) stored at  $-10^{\circ}\text{C}/-20^{\circ}\text{C}$ , and refrigerator thawing (RT) stored at  $-20^{\circ}\text{C}$ ; Group 3: refrigerator thawing (RT) stored at  $-10^{\circ}\text{C}$ ; Group 4: Fresh Meat (FM).

$-20^{\circ}\text{C}$  and subjected to refrigeration thawing (6.52). Unfrozen samples presented lower scores (5.95), which may have occurred because Brazilian consumers generally buy more meat than they need for immediate consumption and usually freeze the remaining meat for a long time (Oliveira and Thébaud-Mony, 1998). The other freezing/thawing treatments presented intermediate scores, with no significant differences between each other ( $p > 0.05$ ).

Lagersted et al. (2008) found no significant differences in sensory attributes between refrigerated and frozen beef samples evaluated by consumers. Muela et al. (2012) found similar results for lamb meat, subjected or not to the freezing process.

According to Leygonie et al. (2012), the thawing process aims to restore the original quality of food, thus, playing an important role in texture, a crucial sensory quality attribute of many foods, including meat. Tenderness and juiciness are the most important attributes for meat texture. According to Shackelford et al. (1995), consumer satisfaction depends on the combination of three quality attributes: flavor, juiciness, and tenderness, and the latter has greater influence on acceptance by consumers.

The results of the external preference map are shown in Figure 3. Most consumer groups showed preference for steaks stored at  $-10^{\circ}\text{C}$  and subjected to microwave thawing, also steaks stored at  $-20^{\circ}\text{C}$  and subjected to refrigeration thawing. These samples were assessed for boiled beef aroma, boiled beef flavor, and internal brown color, whose intensity may influence acceptance by consumers. Few consumers showed preference for unfrozen samples, characterized by apparent juiciness and metallic aroma.

## Conclusions

The methods studied for frozen storage and thawing did not change the sensory quality of Nellore beef steaks to the point to be detected by trained panelists or be rejected by consumers. It can be concluded that the freezing method does not affect most meat attributes. However, when using a faster thawing method, such as microwave and room temperature, tenderness and juiciness could be affected. Freezing beef in lower temperatures may increase consumer perception of sensory attributes, after thawing. Although at short frozen storage (30 days tested in the current work), frozen storage has not had a great influence on sensory properties.

Brazilians usually consume meat subjected to freezing/thawing processes; therefore, they could use frozen storage at  $-10^{\circ}\text{C}$  and microwave thawing, as these methods are cheaper and faster, and showed no differences in the sensory analysis.

## Acknowledgements

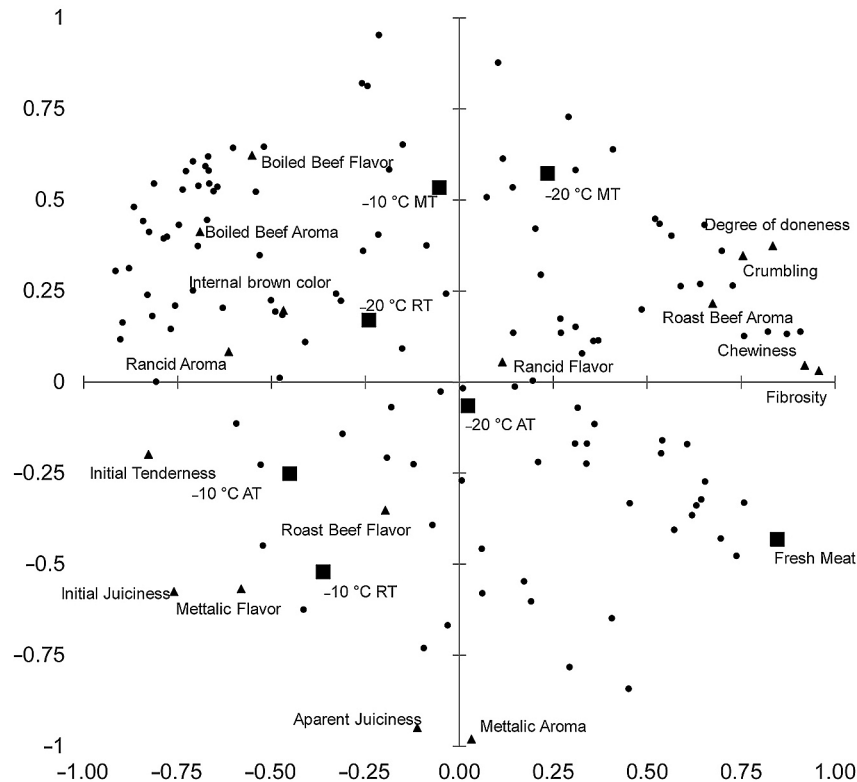
The authors thank the Brazilian National Council for Scientific and Technological Development (CNPq) for providing the financial support for scholarship. This study was financed in part by the Coordination for the Improvement of Higher Level Personnel (CAPES) - Finance Code 001. The authors also thank the JBS Company for donating the meat samples for the study.

## Authors' Contributions

**Conceptualization:** Gomes, C.L.; Silva, T.J.; Pflanzner, S.B.; Bolini, M.H.A. **Data acquisition:** Gomes, C.L.; Silva, T.J.; Pflanzner, S.B.; Bolini, M.H.A. **Data analysis:** Gomes, C.L.; Silva, T.J.; Pflanzner, S.B.; Bolini, M.H.A. **Writing and editing:** Gomes, C.L.; Silva, T.J.; Pflanzner, S.B.; Bolini, M.H.A.

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**Figure 3** – External preference map (x and y are horizontal and vertical axes, respectively) obtained by partial least squares regression of descriptive data and respondents' overall liking scores for the sensory attributes of beef strip loin steaks. Square = treatments; triangle = attributes of quantitative descriptive analysis; black sphere = consumers. Fresh meat; RT = refrigerator thawing; AT = ambient temperature thawing; MT = microwave thawing. –10 and –20 °C: frozen storage temperatures.

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