



## Aging time of five muscles from carcass of Nelore young bulls

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**ABSTRACT.** This trial aimed to assess the qualitative traits of five muscles of 14 Nelore bulls with 450 kg  $\pm$  30.7 kg BW, feedlot fed for 60 days. After slaughter and carcass chilling, samples of the *Biceps femoris* (BF), *Longissimus* (LD), *Gluteus medius* (GM), *Semitendinosus* (ST) and *Trapezius thoracis* (TT) muscles were collected, vacuum-packed and aged at 0 to 2 °C for 1, 7 and 14 days and subsequently stored at -20°C for chemical and quality analysis. The pH, shear force, water holding capacity, cooking losses, meat color and ether extract were evaluated in all aging times. Data were analyzed in a split-plot design using the PROC MIXED procedure of SAS. Aging affected quality traits and chemical properties of the meat, improving aspects, such as tenderness ( $p < 0.01$ ) and lightness ( $p < 0.01$ ). The *Trapezius thoracis* muscle has a higher color stability compared with the *Longissimus* muscle. Aging is not recommended for the ST muscle because the tenderness is not improved. The GM and BF muscles are tender on the first day, and the aging process is indicated for these cuts for adding value to the beef.

**Keywords:** beef cattle, *biceps femoris*, *longissimus*, meat color, Nelore, tenderness.

## Maturação de cinco músculos da carcaça de novilhos da raça Nelore

**RESUMO.** Foram estudadas as características qualitativas de cinco músculos, maturados ou não, de quatorze bovinos da raça Nelore com 450 kg  $\pm$  30,7 kg de peso corporal e confinados por 60 dias com dieta contendo 60% de concentrado e 40% de volumoso na MS. Após o abate e resfriamento das carcaças, amostras dos músculos: picanha, (*Biceps femoris* - BF), contrafilé (*Longissimus* - LD), alcatra (*Gluteus medius* - GM), lagarto (*Semitendinosus* - ST) e acém (*Trapezius thoracis* - TT) foram retirados, embalados à vácuo e maturados em câmara B.O.D (0 a 2°C) por um, sete e 14 dias e posteriormente armazenadas a -20°C para análises químicas e de qualidade. Os dados foram analisados em um delineamento em split-plot utilizando o procedimento PROC MIXED do SAS. A maturação influencia nas características qualitativas e químicas da carne bovina, melhorando aspectos como a maciez ( $p < 0,01$ ) e a luminosidade ( $p < 0,01$ ). O músculo *Trapezius thoracis* tem uma maior estabilidade de cor quando comparado com o músculo *Longissimus*. Não é recomendada a maturação do músculo ST em razão deste não apresentar melhora em sua maciez. Os músculos GM e BF apresentam-se macios logo no primeiro dia, sendo que o processo de maturação para estes cortes é indicado em razão de agregar valor à carne.

**Palavras-chave:** bovinos, cor da carne, cortes cárneos, maciez, Nelore, pH

### Introduction

Tenderness has been considered a major contributor to eating experience in beef (Guerrero, Valero, Campo & Sañudo, 2013; Miller, Carr, Ramsey, Crockett & Hoover, 2001). Aging meat in vacuum packaging at refrigerated temperatures provides purveyors with a way to increase tenderness (Guelker et al., 2013; Voges et al., 2007).

The predominant type of fiber in the musculature of animals has a direct influence on the qualitative traits of the meat, affecting the texture, shear force, color, juiciness, pH, and yield (Aberle, Forrest, Gerrand, Mills & Hedrick, 2001; Maggioni et al., 2012), because these are related to factors such as the muscle

contraction state, degradation of the myofibril, intramuscular fat and diameter of muscle fibers. This affects the meat tenderness directly and indirectly.

Some muscles have a greater physical activity than others, and, as a consequence, they have a large proportion of red fibers among the white fibers (Kirchofer, Calkins & Gwartne, 2002). Myoglobin stores and transports oxygen in the muscles, such that the concentration of myoglobin increases as the oxygen requirement of the muscle is increased, and the levels of these pigments are higher in the most active muscles (Mancini & Hunt, 2005).

Muscles of the forequarter, which perform long periods of physical activity and have a short rest period, have high levels of red fibers (Kirchofer et

al., 2002), as they require much oxygen for their metabolism. The oxidative metabolism requires a well-developed circulatory system and a high concentration of mitochondria and myoglobin. In contrast, muscles that perform fast movements or twitches require a longer rest period. These tissues are rich in white fibers, which, depending in an anaerobic metabolism to obtain energy and need more muscle glycogen in relation to myoglobin. Given the lower concentration of myoglobin, these muscles are less red and thus named 'white' tissues (Cezar & Sousa, 2007). Consequently, there are differences when compared meat color of muscles from the fore- and hindquarter regions of the animals.

Muscles rich in slow-twitch, red(oxidative) muscle fibers are characterized by the presence of myoglobin and lipids, and low glycogen content (Hunt & Hedrick, 1977). As a consequence, metabolism is mostly oxidative and with low lactic acid production, which results in a higher final pH. Muscles consisting mostly of fast-twitch, white muscle fibers (glycolytic) have a high glycogen content and a typically glycolytic metabolism, with a very active degradation of glycogen to lactic acid, promoting lower final pH values (Savell, Muelle, & Baird, 2005).

Fast-twitch muscles (white fibers) have a greater ATPase activity and this should yield tender meat due to the lower activity of calpastatin (Geesink, Kuchay, Chishti & Koohmaraie, 2006), because of the negative correlation between the calpastatin activity and the myofibrillar ATPase activity (Geesink, Taylor, Bekhit & Bickerstaffe, 2001). Therefore, a greater proportion of oxidative fibers reflect in lower activity of calpains, due to a larger amount of calpastatin, resulting in lower muscle degradation and originating a less tender meat (Koohmaraie, 1996).

Nevertheless, in order to increase the overall value of the carcass, it is necessary to study these muscles, which will demystify some aspects and provide an increased consistency of products, promoting a more effective commercialization as well as guidance in the use of processing technologies, as in the case of aging (Macedo et al., 2008; Tschirhart-Hoelscher, Taylor, Bekhit & Bickerstaffe, 2006). Aging allows for a significant improvement in tenderness, and this procedure can be advantageous from the qualitative point of view, especially when it comes to animals with a greater *Bos indicus* genetic composition (Maggioni et al., 2012; Wheeler, Cundiff & Koch, 1994).

It is there for interesting to improve and differentiate meat cuts, mainly in relation to its

qualitative aspects, as several market studies have shown that consumers have paid a higher value in meat products which have according to their preferences. Thus, this study aimed to evaluate the effects of different aging times on the quality traits of five muscles of Nellore young bulls.

## Material and methods

The trial was carried out at the São Paulo State University (UNESP, Jaboticabal, São Paulo State, Brazil), following the humane animal care and handling procedures, according to the guidelines of the São Paulo State University (UNESP, Brazil). Fourteen Nellore young bulls with average initial body weight of  $450 \pm 30.7$  kg and age of 15 months were used. Initially, cattle were weighed, identified and housed in individual pens with trough and drinkers. Cattle were subjected to seven days of adaptation to experimental installations and diets. After this period, the animals were fed for 60 days. Diets were formulated according to Valadares Filho (2006) and offered in the concentrate level of 40:60. Corn silage was used as the exclusive roughage and concentrate was composed of ground corn, soybean meal, urea/ammonium sulfate and mineral mixture (Table 1).

**Table 1.** Diet composition.

Ingredients (% DM)	
Corn silage	40.00
Corn	46.40
Soybean meal	10.00
Urea / ammonium sulfate	0.60
Mineral supplement <sup>1</sup>	3.00
Chemical composition (%)	
Dry matter	67.08
Crude protein	14.45
NDF	25.19
Ether extract	3.18
NFC	53.93

<sup>1</sup>Composition (Ca: 210 g; P: 20 g; S: 37 g; Na: 80 g; Cu: 490 mg; Mn: 1.424 mg; Zn: 1.830 mg; I: 36 mg; Co: 29 mg; Se: 9 mg; Flmax.: 333 mg).

After 60 days of feeding, animals were slaughtered at a commercial abattoir with  $598 \pm 41.7$  kg of shrunk body weight. Pre-harvest handling was in accordance with good animal welfare practices, and slaughtering procedures followed the Sanitary and Industrial Inspection Regulation for Animal Origin Products.

After the slaughter, carcasses were weighed and then refrigerated at 0°C for approximately 24h. After the postmortem chill period, samples of the following muscles were removed from the left carcasses: *Biceps femoris* (BF), *Gluteus medius* (GM), *Longissimus* (LD), *Semitenidosus* (ST) and *Trapezius thoracis* (TT). Three samples were taken from each muscle to evaluate the variable of meat quality in its respective time.

The samples were aged for 7 or 14 days between 0 and 2°C and subsequently stored at -20°C for analysis.

The pH, shear force, water holding capacity, cooking losses, meat color and ether extract were evaluated in all aging times.

Warner–Bratzler shear force (WBSF) steaks were thawed at 4°C for 24h and oven-broiled in an electric oven (Ltedesco) preheated at 175°C. Internal steak temperatures were monitored by 20-gauge copper-constantan thermocouples placed in the approximate geometric center of each steak and attached to a digital monitor. When internal steak temperature reached 35°C, the steak was turned over and allowed to reach an internal temperature of 71°C before removal from the oven. Cooked WBSF steaks were cooled for 24h at 4°C (AMSA, 1995). Eight round cores (1.27 cm diameter) were taken from each steak parallel to the long axis of the muscle fibers (AMSA, 1995). Each core was sheared once through the center, perpendicular to the fiber direction by a Warner–Bratzler shear machine (Brookfield Texture Analyser). Cook loss (CL) was evaluated on the steaks that were also used for WBSF measurement. Total CL was calculated as the difference between the weight of the steaks before and after oven-broiling.

The determination of meat and fat color was performed as described by Houben, Van Dijk, Eikelenboom and Hoving-Bolink (2000), using a Hunterlab colorimeter to evaluate the lightness (L\*), redness (a\*), and yellowness (b\*). Color aspects were assessed by the CIE L\*a\*b\* color system using 0°/45°. Thirty minutes before the assessment, cross sections were made at the samples surface to expose themyoglobin to oxygen, as described by Abularach, Rocha, and Felíc (1998), the same steps were made for the fat color measurement. After this, the color was measured at three different points and average values calculated. The colorimeter was calibrated before analyzing the samples against white and black standards.

After evaluating each steak's color, approximately 2 g was collected to determine the water holding capacity (WHC). This value is the difference between the weights of the sample before and after being subjected to a pressure of 10 kg for 5 min. (Hamm, 1986).

The ultimate pH was measured on the aged muscles of each animal using a pH-meter with automatic endpoint and buffer cognition as well as temperature compensation equipped with a penetrating electrode (Model SG2 — ELK, Seven Go™, Mettler Toledo International Inc.). The pH-meter was calibrated before use to pH 7.0 and 4.01. The pH was measured at approximately 4 cm deep on the muscles.

For proximate analysis, the epimysium was removed from the samples before lyophilization for 48h. Samples were then ground and analyzed for

ether extract (EE; Method 920.85) (AOAC, 2005) in order to determine the chemical composition of each aged samples.

Data were analyzed in a split-plot design using PROC MIXED procedure of SAS (2004). The model tested the fixed effects of muscle, aging time and their interaction. Muscle (animal) was included in the model as a random effect. When no significant interaction was removed from the model. The means squares were generated for the main effects and significant interactions were separated ( $p < 0.05$ ) using the Tukey's test.

## Results and discussion

No interactions were detected between aging times and muscles (Table 2) for pH, L\* and EE; thus, the results were discussed separately. The pH of TT muscle was higher ( $p = 0.04$ ) than in other muscles. In the present study, the aging reduced the pH values in relation to the beef evaluated at the time 1, where in the pH dropped on day 7 (5.2) and increased again on day 14 (5.7), but with a lower value in relation to day 1 (5.7).

The control of pH is important, as it is related to color, tenderness and WHC of the meat (Valero et al., 2014; Zawadzki et al., 2011). Muscle pH usually decreases from 7.0 after slaughter to approximately 5.3 to 5.8 after chilling, such that the pH drop during the chilling occurs between 6 and 12 h and is completed in 18 to 40 h after slaughter (Savell et al., 2005). According to Luchiaro Filho (2000), a decrease in pH is due to the use of reserves of glycogen and its transformation into lactic acid by anaerobic glycolysis. Therefore, on day 1, the pH was at normal levels, which is in agreement with the meat-packing-industry standards, given that in Brazil meat packing plants export only meat with pH lower than 5.8 (Fernandes et al., 2008).

Vacuum-packaging delays the growth of aerobic putrefactive bacteria and also promotes the growth of lactic bacteria, which in turn produce antimicrobial substances (Puga, Contreras & Turnbull, 1999). Hence, although microbial growth was not evaluated in the present study, it can be inferred that the lower pH observed on days 7 and 14 was due to the growth of lactic bacteria and production of acid substances, which contributed to the increased growth in the meat environment.

The difference in pH observed for the muscles ( $p = 0.04$ ) in the present study can be related to the amount of glycogen. Muscles from the forequarter, e.g., TT, which perform long periods of physical activity and have a short rest period, have a greater proportion of red fibers and are characterized by the presence of myoglobin and lipids, but low glycogen levels (Hunt & Hedrick, 1977). Thus, their

metabolism is preferentially oxidative and with low lactic-acid production, which explains why the TT muscle in our study showed a higher pH. Muscles that are composed mainly of white muscle fibers (LD, GM, ST and BF), however, have high glycogen content and a typically glycolytic metabolism, with a highly active degradation of glycogen to lactic acid, promoting lower pH levels (Savell et al., 2005).

Higher  $L^*$  values were observed at 7 and 14 days, differing from day 1, which showed a lower value

( $p < 0.01$ ). Among the muscles, ST showed greater  $L^*$  than LD, GM, BF and TT ( $p < 0.01$ ).

Aging increases the meat  $L^*$ , resulting in brighter meats (Mancini & Hunt, 2005). According to Pereira, Sobral, Leme and Silva (2008), an explanation for the increase in  $L^*$  with aging is the presence of a greater amount of liquid on the surfaces, and hence the greater moisture and higher values for this trait in the aged meat.

Protein degradation in the aging period is directly related to the pH, which changes the light dispersion properties and consequently affects the  $L^*$  values (Kadim et al., 2013), and lower pH values will allow for greater meat  $L^*$ . With higher muscle pH, proteins are able to bind more strongly to water, yielding less free water. When the proteins bind to more water, the muscle fibers are swollen, leaving less space between muscle fibers (Page, Wulf & Schwotzer, 2001). Therefore, meats with a higher pH will be darker in color because there is less free water to reflect light (Mancini & Hunt, 2005). Therefore, due to the lower pH found with the aging time, some muscles showed lower WHC, which made it possible to increase the luminosity index with the aging time.

A higher  $L^*$  value was found in the ST muscle, which can be explained by its anatomical position, with a more external location and a denser and more visible connective tissue, due to its function in the animal, with lower iron levels and consequently greater luminosity (Mancini & Hunt, 2005).

The lowest EE value was observed on day 14 in relation to the other aging times ( $p = 0.03$ ). The highest EE value for the muscles was obtained in BF, and muscles LD and TT did not differ from BF and GM. The ST muscle showed the lowest value, not differing from GM ( $p = 0.05$ ) (Table 2).

The lipid content is influenced by several factors such as sex, breed, feeding, and the anatomical location of the beef cut (Moreira et al., 2003; Prado et al., 2011; Prado et al., 2008; Rotta et al., 2009a; 2009b). According to Rotta et al. (2009b), the beef intramuscular fat content is 3 to 5%. Nevertheless, the percentage of total lipids observed in the different cuts analyzed varied from 4.41%, in ST, to 6.17% in BF.

Evidence shows that the minimum content of lipids necessary to obtain a tender and juicy beef is 2.9-3.0% (Campion, Crouse & Dikeman, 1975). However, even though the EE values found in the present study are within the range considered appropriate, the cuts such as the LD, ST and TT muscles showed high shear forces on the first day. This may be related to the composition of the muscle fibers as well as the number of thermostable collagen crosslink.

The WHC,  $a^*$  and  $b^*$  intensities, CL, and WBSF variables showed an interaction between muscles and aging time (Table 3). The highest values for  $a^*$  were obtained by BF and LD on day 14, and the lowest was found in ST at 7 days of aging ( $p < 0.01$ ).

In general, increasing the postmortem aging time decreases the color stability of fresh meat. There have been several studies that have looked at how aging meat in vacuum packaging affects instrumental color values.

A study conducted by Leisner, Greer, Dilts and Stiles, (1995) found that increasing beef postmortem aging time in vacuum packaging decreased  $a^*$  values (redness) when placed into a simulated retail display. In lamb loins, similar results were shown as increasing aging time in vacuum packaging from 14 days to 63 days increased discoloration and decreased  $a^*$  values (Kim, Luc & Rosenfold, 2013). Lee, Apple, Yancey Sawye & Johnson, (2008) found that beef *Gluteus medius* steaks from top sirloin butts aged in vacuum packaging for 7 and 14 days had increased chroma values,  $a^*$  values,  $b^*$  values, and oxymyoglobin percentages compared to steaks from top sirloin butts aged in vacuum packaging for 28 and 35 days.

The difference in beef color may be related to the type of muscle fiber (Hood, 1980). Red fibers (oxidatives) will have higher concentrations of mitochondria that typically compete with myoglobin for oxygen consumption, reducing the oxymyoglobin layer and giving a darker appearance to the muscle (Monin, 1991, 1998).

These results suggest that the muscles classified as red would have a faster discoloration rate and an increase in metmyoglobin production under aerobic exposure. However, the present study hypothesized that vacuum-packed muscles from the forequarter show a similar discoloration rate to muscles from the hindquarter, because when the oxygen is removed, the process of discoloration is slowed down. Thus, the TT, a red-fiber muscle which showed constant  $a^*$  values, and this fact may be related to the anaerobic condition imposed to the muscle. Therefore, there will be less competition between mitochondria and myoglobin for oxygen, so  $a^*$  will be kept at normal values.

**Table 2.** pH, lightness(L\*) and ether extract (EE) from beef aged of Nellore young bulls finished in feedlot.

Item	Aging time (days)			SEM	P	Muscles <sup>1</sup>					EPM	P	ATxM <sup>2</sup>
	1	7	14			LD	GM	BF	ST	TT			
pH	5.72 <sup>a</sup>	5.25 <sup>c</sup>	5.67 <sup>b</sup>	0.02	< 0.01	5.53 <sup>b</sup>	5.48 <sup>b</sup>	5.51 <sup>b</sup>	5.55 <sup>b</sup>	5.66 <sup>a</sup>	0.04	0.04	0.14
L*	41.27 <sup>b</sup>	42.90 <sup>a</sup>	43.33 <sup>a</sup>	0.39	< 0.01	41.24 <sup>b</sup>	41.19 <sup>b</sup>	39.90 <sup>b</sup>	49.52 <sup>a</sup>	40.63 <sup>b</sup>	0.75	< 0.01	0.82
EE <sup>3</sup> , %	5.34 <sup>a</sup>	5.51 <sup>a</sup>	4.60 <sup>b</sup>	0.29	0.03	5.56 <sup>b</sup>	4.55 <sup>bc</sup>	6.17 <sup>a</sup>	4.41 <sup>c</sup>	5.11 <sup>ab</sup>	0.45	0.05	0.45

<sup>1</sup>LD - Longissimus; GM - Gluteus medius; BF - Biceps femoris; ST - semitendinosus; TT - Trapezius thoracis; <sup>2</sup>Interaction between aging times x muscles; <sup>3</sup>% of natural matter.

**Table 3.** Interaction between muscles and aging times for the meat quality traits of Nellore young bulls.

Aging time	Item				
	a*	b*	WHC (%)	WBSF (kgf)	CL (%)
	Longissimus				
Day 1	15.18 <sup>cd</sup>	13.74 <sup>f</sup>	73.96 <sup>a</sup>	5.05 <sup>ab</sup>	32.87 <sup>cd</sup>
Day 7	15.87 <sup>bc</sup>	14.51 <sup>ef</sup>	68.26 <sup>c</sup>	4.11 <sup>cd</sup>	29.65 <sup>e</sup>
Day 14	16.87 <sup>a</sup>	14.94 <sup>de</sup>	72.23 <sup>ab</sup>	3.72 <sup>de</sup>	30.11 <sup>cd</sup>
	Gluteus medius				
Day 1	16.24 <sup>ab</sup>	14.54 <sup>ef</sup>	72.50 <sup>a</sup>	4.38 <sup>bc</sup>	28.64 <sup>e</sup>
Day 7	15.25 <sup>cd</sup>	14.55 <sup>ef</sup>	70.20 <sup>ab</sup>	3.68 <sup>de</sup>	29.60 <sup>e</sup>
Day 14	16.29 <sup>ab</sup>	15.93 <sup>c</sup>	69.50 <sup>c</sup>	4.02 <sup>cd</sup>	31.19 <sup>cd</sup>
	Biceps femoris				
Day 1	15.09 <sup>cd</sup>	12.73 <sup>f</sup>	72.67 <sup>a</sup>	3.48 <sup>de</sup>	28.42 <sup>e</sup>
Day 7	15.07 <sup>cd</sup>	13.25 <sup>e</sup>	72.18 <sup>ab</sup>	4.12 <sup>cd</sup>	33.82 <sup>ab</sup>
Day 14	16.94 <sup>a</sup>	14.97 <sup>de</sup>	72.35 <sup>ab</sup>	3.60 <sup>de</sup>	31.70 <sup>cd</sup>
	Semitendinosus				
Day 1	14.96 <sup>cd</sup>	17.06 <sup>b</sup>	71.06 <sup>ab</sup>	5.59 <sup>a</sup>	33.40 <sup>bc</sup>
Day 7	14.01 <sup>c</sup>	17.22 <sup>b</sup>	68.69 <sup>c</sup>	5.60 <sup>a</sup>	36.73 <sup>a</sup>
Day 14	14.74 <sup>de</sup>	18.22 <sup>a</sup>	71.76 <sup>ab</sup>	5.48 <sup>a</sup>	34.76 <sup>b</sup>
	Trapezius thoracis				
Day 1	16.48 <sup>ab</sup>	13.78 <sup>g</sup>	72.96 <sup>a</sup>	4.97 <sup>ab</sup>	29.93 <sup>de</sup>
Day 7	16.30 <sup>ab</sup>	14.82 <sup>de</sup>	68.61 <sup>c</sup>	4.22 <sup>bed</sup>	35.68 <sup>ab</sup>
Day 14	16.27 <sup>ab</sup>	14.63 <sup>e</sup>	68.92 <sup>c</sup>	2.96 <sup>c</sup>	28.14 <sup>e</sup>
SEM	0.38	0.39	0.80	0.32	1.28
	P-value*				
Muscles (M)	< 0.01	< 0.01	0.02	< 0.01	< 0.01
Aging time (AT)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Interaction M x AT	< 0.01	0.03	< 0.01	< 0.01	< 0.01

For the b\* intensity, the highest value was found in the ST muscle on day 14, followed by days 7 and 1. The lowest values were obtained for the BF muscle on days 1 and 7 (Table 3). All muscles showed high b\* values throughout the aging time (p = 0.03). Aged muscles show a greater yellow intensity, as observed in all studied muscles, which is attributed to storage and temperature. At higher temperatures, there is an acceleration in the pigment oxidation rate and an increase in the oxidizing reaction inside the tissue (Faustman & Cassens, 1990), due to the reduced antioxidant defense and increased lipid oxidation rate resulting from the activity of free radicals (Renerre, 2004), which may also increase the oxidation of myofibrillar proteins (Rowe, Maddock, Lonergan & Huff-Lonergan, 2004).

The LD, GM, BF and TT muscles showed their greatest WHC on day one. Intermediate values were obtained for LD on day 14; GM on day 7; BF on days 7 and 14; and ST on days 1 and 14. The lowest values were found for LD on day 7; GM on day 14; ST on day 7; and TT on days 7 and 14 (Table 3).

A significant difference could be observed in the WHC for the ST and LD muscles on day 7, and

then this value increased significantly on day 14. During the conversion of muscle to meat, lactic acid accumulates in the tissue, thus reducing meat pH. Once the pH has reached the isoelectric point of the main proteins, especially myosin, the protein net charge is zero, meaning that the number of positive and negative charges in the proteins is essentially the same (Huff-Lonergan & Lonergan, 2005).

According to Lawrie (1977), the formation of lactic acid and the consequent drop in pH are responsible for the reduced WHC of meat during the application of forces such as cutting and heating; and at pH of 5.2 to 5.3 (IEP of the muscle proteins, with balance of positive and negative charges), the meat has a lower WHC. This fact was observed on day 7, when there was a decrease in pH, thereby reducing the WHC in the ST and LD muscles.

The TT muscle reduced its WHC with aging. This muscle is rich in red fibers, having a higher pH in relation to the other muscles. At a higher pH, the WHC is higher; thus, in the evaluation of WHC, it will lose more water than the other muscles. This can be related to the anatomical position of this muscle, which is a section from the forequarter, the others being from the hindquarter. Reduction in WHC is not desirable from the commercial aspect, because it will affect the juiciness of beef, making it drier (Huff-Lonergan & Lonergan, 2005).

The shear force evaluation demonstrated that the ST muscle exhibited the highest values at all aging times (p < 0.01). Thus, for this muscle, aging did not affect the tenderness until 14 days. According to Shackelford et al. (1991), values up to 4.5 characterize a tender beef. Therefore, the GM and BF muscles can be considered as tender on the first day of evaluation, so the aging is not justified.

Stolowski et al. (2006) grouped muscles regarding their sensitivity to aging, and observed that the GM and LD muscles have a slow response; ST has a low response, and BF does not respond to aging. The non-significant improvement in texture in the BF muscle may be related to the low calpain values (Koochmaraie, Seideman, Schollmeyer, Dutton & Babiker, 1988), as well as the high collagen level (Hildrum et al., 2009).

The lowest SF was verified in the TT muscle when subjected to aging for 14 days. In agreement with

Shackelford, Morgan, Cross and Savell (1991), several studies demonstrate the influence of pH on the activity of cathepsins and calpains, which are proteolytic enzymes, suggesting that the observed differences in pH may be partially responsible for the differences in tenderness. The muscle from the forequarter utilized in the study, showed higher pH and tenderness in relation to the muscles from the hindquarter. The variation in tenderness may also be attributed to the connective tissue (McCormick, 1994). The same author also stated that muscles with little connective tissue resulted in tender meat as compared with those with a higher level of connective tissue. Muscles with a higher proportion of white fibers present a higher amount of connective tissue (Melton, Dikeman, Tuma & Kropf, 1974, 1975); thus, the TT muscle is considered to be a muscle with a greater proportion of red fibers, which provides a lower level of connective tissue.

For the LD muscle, a decrease in SF was observed from day 1 to 14, and the same trend was detected for TT. Therefore, aging was effective for the tenderness of these two muscles (Table 3).

When different muscles are aged, the main objective is to evaluate the aging efficiency as a technique to improve the texture of muscles from the forequarter considered as tougher, and consequently of lower economic value, aiming to standardize them with tender muscles as well as add value to products that already have an acceptable tenderness.

In fact, most aging effects occur until the 14 days *postmortem*, in which the shear force is reduced, and maximum tenderness was found at 14 days (Miller, et al., 2001). However, studies have shown that seven days of aging are sufficient to eliminate genetic differences reflected in the tenderness of meat from Zebu animals (Maggioni et al., 2012; Morales et al., 2003), which was observed in the present study for the LD muscle.

Bianchini et al. (2007) reported no differences in beef shear force of *Longissimus dorsi* between 7 and 14 days of aging; however, this variable was reduced as compared with day zero. This demonstrates that aging can improve beef tenderness.

Higher CL values were registered for the ST muscle on day 7, and the BF and TT muscles on day 7 did not differ from ST. The lowest values were found for LD on day 7, GM on days 1 and 7, BF on day 1 and TT on day 14. Comparing day 1 with 14, there was no significant difference in CL for the LD, ST and TT muscles ( $p < 0.01$ ). This effect is desirable, because when these muscles are aged for 14 days, CL will not be impaired (Table 3). This fact is desirable for aging,

because it means that CL will not be affected if the cut is aged for 14 days, so the meat juiciness will be preserved.

The ST muscle obtained higher CL on day 14, and this effect can be compared to the high shear-force values. According to Oliveira et al. (2012), CL values can be influenced by WHC, which is considered a very important trait for consumption, where in low values are related to a lower nutritional value, resulting in drier and less tender meat.

## Conclusion

Aging affects the qualitative and chemical properties of beef, improving aspects of tenderness and lightness.

The *Trapezius thoracis* muscle has a higher color stability as compared with the *Longissimus* muscle, and it can be aged in vacuum-package for 14 days without changes in the redness ( $a^*$ ).

Aging is not recommended for the *Semitendinosus*, because it does not improve its tenderness. The *Gluteus medius* and *Biceps femoris* are tender on the first day, and the aging process is indicated for these cuts to add value to the beef.

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