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# Qualitative traits of aged m. triceps brachii and m. gluteus biceps from lambs on supplemented feed

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**ABSTRACT**

The aim of this study was to evaluate the effect of the supplementation and aging in the gluteus biceps and triceps brachii muscles of lamb. Forty-eight Santa Inês lambs, with 15 kg average initial weight were slaughtered at 32 kg average final weight, after five months of supplementation. Twenty-four animals were allocated to sixteen pastures with residual leaf area index (2.6) and unsupplemented, the other twenty-four animals were allocated to the same conditions but were supplemented. The treatments were cross factorial between rLAI (2.6) and supplemented or not, totalizing 8 treatments. In this experiment, the slaughter criterion was the age of the animals. In the gluteus biceps and triceps brachii muscles, storage for seven days increased lipid oxidation. The values of cooking loss and water holding capacity increased with time of aging and were higher in the gluteus biceps, by 29.40% and 71.30%, respectively. The supplementation implies an increase in production costs, but its use provides the quantitative and qualitative characteristics favorable to the product, aiming to satisfy the consumer market. The supplementation decreased the shelf life, increasing the lipid oxidation during time of aging and affected the lightness and the hue of yellow, which may sffect consumers' intention to purchase.

**Key words:** lipid oxidation; myofibrillar fragmentation index; redness; shelf life; shear force; tenderness; yellowness

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## Introduction

Sheep have advantageous features in their procreation and opportunities for profitable production, for small, medium and large producers, especially with the increased demand for healthy food and a preference for products with higher protein and low cholesterol values, saturated fats and calories, as in the case of ovine meat (NETTO and TORRES, 2008).

In production systems, adaptation of feed is an opportunity to exploit the potential gain of young animals, however, it can be an economically demanding, because of the feed costs, which represent about 70% of the total value of production (BARROS et al., 2009). Therefore, production in pastures is an alternative being used, but there is poor weight gain and therefore a longer time to slaughter. Aiming at consumer demands for tender meat from young-slaughtered animals, the productive sector has used pasture supplementation, to improve production rates, and aging to improve the sensory traits of the final product. VOLTOLINI et al. (2008) reported that the use of supplementation with concentrate for grazing animals must meet the basic conditions, such as the genetic potential of the animals, and the quality and quantity of available forage.

Time of aging is a process that occurs after *rigor mortis* and consists of natural changes that occur in the meat during storage, involving the effect of temperature and storage period at temperatures close to 0 °C which can cause alterations in the sensory traits of meat (LAWRIE 1985; KUBOTA et al., 1993; PUGA et al., 1999). The time of aging improves the most important sensory characteristic for the consumer after purchasing the product, tenderness (VEISETH and KOOHMARAIE et al., 2001). BORGES et al., (2006) studying the effect of muscle type and maturity of some sensory characteristics of goat meat, concluded that the aging for seven days favors the tenderness of the meat of the semimembranosus and biceps femoris muscles, but does not affect the meat of the longissimus dorsi muscle.

The aim of this study was to evaluate the effect of supplementation on fresh and aged meat from lambs, from the gluteus biceps and triceps brachii muscles.

## Materials and methods

*Experimental area.* The experiment was performed at the Universidade Estadual Paulista - FCAV/ UNESP, Câmpus de Jaboticabal, São Paulo, Brazil (21°08' S, 48°11' W, 583 m altitude) from October 2011 to March 2012. The animals were reared in the Forage Sector and slaughter was in the same place. The qualitative analyses were performed at the Laboratory of Technology of Animal Products. The experiment was reviewed and approved by the Ethics Committee for the Use of Animals from São Paulo State University (Jaboticabal, São Paulo, Brazil) by protocol number 004633/13.

*Animals and treatments.* Forty-eight uncastrated male lambs, Santa Inês breed, at approximately 120 days old and 15 kg of initial body weight were used in this study. These animals were allocated to thirty-two paddocks (100 m²) enclosed by fences 1.20 m in height, divided by electric fences (5.000 V) with four strands of wire. Mobile sunshades were allocated to the paddocks so the animals could protect themselves in the hottest hours of the day. All the animais remained in these paddocks with *Cynodon dactylon* cultivar Tifton-85 for around 10 hours a day, from 6:00 am to 4:00 pm, with residual leaf area index of 2.6.

Table 1 presents the chemical composition of *Cynodon dactylon* cultivar Tifton-85 in the paddocks where animals were kept during the trial, expressed on a dry matter basis. The leaf area index (LAI) and light interception (LI) of the leaves were monitored at the time of entry of the animals into the rotational paddocks (pre-grazing), and during the grazing daily measurements were taken until they reached a residual leaf area index of 2.6. The LAI and the LI, were determined using the canopy analyzer equipment AccuPAR LP-80 (Decagon Devices, Inc., Pullman, WA, USA), consisting of a bar with light sensors that capture the radiation (at a frequency of 400-700 nm) either above the canopy or on ground level. The LI monitoring of the canopy was carried out at the time when the animals were removed from the paddocks and during the pasture regrowth. The LI measurements were performed weekly until the LI value was close to 95%, and then on a daily basis until LI reached 95%. The LAI was monitored at the time of entry of animals into the paddocks (pre-grazing) and during grazing, being measured daily until it reached the predetermined LAI. The animals were led to another paddock that had reached the LI target of 95% of during the rest period.

Table 1. Chemical composition of *Cynodon dactylon* cultivate Tifton-85

| Nutrients | % |
|---|---|
| CP | 9.2 |
| DM | 93.0 |
| FAT | 1.4 |
| NDF | 66.4 |
| ADF | 37.2 |
| TDN | 61.0 |
| ASH | 6.1 |

CP - crude protein; DM - dry matter; FAT - fat; NDF - neutral detergent fiber; ADF - acid detergent fiber; TDN - total digestible nutrients; ASH - ash

Twenty-four animals were allocated to sixteen pastures with residual leaf area index (2.6) and unsupplemented, the other twenty-four animals were allocated under the same conditions but were supplemented. There were four pastures per treatment with six

animals. The treatments were a cross factorial between rLAI (2.6) and supplemented or not, totalizing 8 treatments. In this experiment, the slaughter criteria were the ages of the animals.

After 4:00 pm, the supplemented animais (24 animals) were kept in individual stalls, receiving protein-energy supplement at around 0.7% of body weight (0.7% BW) (Table 2). The animals were dewormed for control of endoparasites and identified with numerical markings on a necklace, attached to the neck.

Table 2. Composition of commercial supplement offered to supplemented animals

| Product guarantee levels (%) | |
|---|---|
| Crude protein | 18 |
| NNP - Equal protein | 8 |
| Fat | 0.1 |
| TND | 0.7 |
| Fibrous matter | 18 |
| Mineral matter | 19 |
| Moisture | 12 |
| Calcium | 2 |
| Phosphor | 0.4 |
| Enrichment product per kilogram (mg) | |
| Sodium | 4.500 |
| Sulfur | 3.300 |
| Copper | 16 |
| Manganese | 47 |
| Zinc | 61 |
| Iodine | 1.2 |
| Cobalt | 1 |
| Selenium | 0.3 |
| Monensin | 45 |

The animals were weighed weekly, and the color of the conjunctiva of the eye mucosa evaluated fortnightly, by the Famacha® method, according to the recommendations of MOLENTO et al., (2004).

*Slaughter and sample collection.* The animals were weighed on a weekly basis and when they reached 32 kg of body weight in each group, the lambs fasted from solid diets for 16 hours prior to slaughter. Lambs were stunned by eletronarcosis (220 V) for eight seconds, which was followed by bleeding, by sectioning the jugular veins and carotid artery. After bleeding, carcasses were weighed and refrigerated (2 ± 2 °C) for 24 hours. At 24 hours *post mortem*, the triceps brachii and gluteus biceps muscles from the right half of

the carcass were collected, labeled, vacuum packed and aged (0 ± 1 °C) in a Biochemical Oxygen Demand (BOD) incubator (Eletrolab EL101/3 250W, Eletrolab, São Paulo - SP, Brazil) for seven days. The physical analyzes were performed before (control) and after aging for seven days. Samples for chemical analysis, at each sampling time, were frozen at -20 °C for 30 days for further analysis.

*Methods.* The color, pH, water holding capacity (WHC), cooking loss (CL), shear force (SF), lipid oxidation and myofibrillar fragmentation index (MFI) were analyzed. Color (L* - lightness, a* - redness, and b* - yellowness) were measured using a Minolta CR-400 colorimeter (Konica Minolta Sensing, Inc., Osaka, Japan), in three different places on each sample immediately after deboning and, in aged samples, 30 minutes after opening packages and exposing samples to oxygen. Meat pH was measured in triplicate using a pHmeter Testo (205, Testo Inc., Sparta, NJ, USA) with a penetration electrode inserted into the *triceps brachii* and *gluteus biceps* muscle samples.

The WHC was determined according to HAMM (1960) using 2 g of muscle sample placed between paper filters and acrylic plates, and subjected to the pressure exerted by a 10 kg weight, for five minutes. Subsequently, samples were weighed again. The results were expressed as a percentage showing the difference between the initial and final weights.

The CL was determined in samples 2.5 cm thick, which were cooked on a grill, preheated for 10 minutes, until 71 °C internal temperature was reached, controlled using thermocouples (Flyever Ind. e Com. de Equip. Eletr. Ltda., São Carlos, São Paulo, Brazil) inserted individually into each sample according to WHEELER et al. (2005). After cooking, samples were cooled at room temperature and reweighed. The weight loss was calculated by the difference between the initial and final weights, expressed as a percentage. From the cooked samples, cylindrical subsamples were obtained with known diameter (1.27 cm), placed with the fibers oriented perpendicularly to a Warner-Bratzler shear device, coupled to a TA-XT2i texture analyzer (Stable Micro Systems, LTD., Godalming, UK) to determine shear force (WHEELER et al., 2005) and the force required for shearing the samples was expressed in Newtons (N).

The lipid oxidation was determined as described by VYNCKE (1970), analyzing the thiobarbituric acid reactive substances (TBARS). Ground and raw samples (5 g) were weighed in falcon tubes, to which 25 mL of trichloroacetic acid solution was added (7.5%). After homogenization in a turrax device, followed by filtration, an aliquot of 5 mL was pipetted and placed into test tubes containing an additional 5 mL of thiobarbituric acid solution (0.29%). Samples were kept in a water-bath at 96 °C for 40 minutes, and, after cooling at room temperature, measurements were performed on a spectrophotometer at 538 nm accompanied by a standard curve.

The myofibrillar fragmentation index (MFI) was determined according to CULLER et al., (1978). From frozen samples, 3 g of subsamples were obtained and chopped with a scalpel to remove any visible fat and connective tissue. Samples were homogenized in a turrax device for 1.5 minutes, with 30 mL of extraction buffer (KCl, $KH_2PO4$, $K_2HPO_4$, EDTA, $MgCl_2$, $NaN_3$). The homogenate was centrifuged for 15 minutes at 10,000 rpm and at 4 °C. After discarding the supernatant, the precipitate was dispersed into 30 mL of extraction buffer, stirred with a glass rod and centrifuged again. This operation was repeated three times. After discarding the supernatant, 15 mL of extraction buffer was added to the precipitate and the resulting suspension was filtered to remove connective tissue. The protein concentration of the myofibril suspension was determined by the biuret method, as described by GORNALL et al., (1949). The standard curve was obtained with different dilutions between bovine serum albumin (BSA) + sodium azide and saline solution (9 points). An aliquot from the suspension of myofibrils was diluted with extraction buffer to a protein concentration of 0.5 ± 0.05 mg/mL. The diluted suspension of myofibrils was stirred and, shortly thereafter, its optical density was measured in a spectrophotometer at 540 nm. The MFI was calculated according to the formula: MFI = optical density ×200, expressed in absolute numbers.

All analyzes were performed on fresh meat, aged for seven days from both muscles.

*Statistical analysis.* Data were analyzed following a completely randomized design with a 2 × 2 × 2 factorial arrangement of treatments (two times of aging, two muscles and two supplementation levels), with 10 replicates. Data were analyzed using analysis of variance, using the Mixed procedure (SAS Inst., Inc., Cary, NC). The statistical model included the fixed effects of time of aging, muscles, supplementation level, and double interactions between these effects. The results were submitted to analysis of variance and, if significant, compared by Tukey's test with a significance level of $P<0.05$.

**Results**

The pH of triceps brachii and gluteus biceps were statistically similar and were not affected by the time of aging or supplementation (Table 3). The lightness (L*) decreased with supplementation; redness (a*) was higher in the triceps brachii ($P = 0.0014$) and when aged for seven days ($P = 0.0166$). The yellowness (b*), lipid oxidation (TBARS) represented the interaction between time of aging-muscle and time of aging-supplementation, while for CL, WHC, MFI and SF force interaction between time of aging-muscle was presented.

The gluteus biceps showed higher yellowness than the triceps brachii muscle and the yellowness decreased in the triceps brachii and increased in gluteus biceps samples during the aging period. The gluteus biceps also presented higher lipid oxidation than the triceps brachii and this increased in both muscles after the time of aging (Table 4).

It was observed that the yellowness of meat from supplemented animals after the aging process increased from 5.41 to 7.39. However, the yellowness of the meat from the non-supplemented group decreased from 5.32 to 3.81, for the control and aged meat, respectively (Table 5).

Table 3. Estimated average ( ± standard error) of pH, lightness (L*), redness (a*), yellowness (b*), lipid oxidation (TBARS, mg malonaldehyde/kg), cooking loss (CL, %), water holding capacity (WHC, %), myofibrillar fragmentation index (MFI), shear force (SF, N) of fresh or aged meat from two muscles, from supplemented or non-supplemented lambs

| | L* | a* | b* | pH | WHC (%) | CL (%) | SF (N) | TBARS | MFI |
|---|---|---|---|---|---|---|---|---|---|
| Time of aging (TA) | | | | | | | | | |
| 0 | 45.01 ± 0.27 | 18.04 ± 0.12$^{B}$ | 5.36 ± 0.13 | 6.32 ± 0.04 | 83.78 ± 0.37$^{A}$ | 26.60 ± 0.48$^{B}$ | 33.83 ± 0.06$^{A}$ | 0.112 ± 0.003$^{B}$ | 115.04 ± 0.32$^{B}$ |
| 7 days | 45.60 ± 0.27 | 19.21 ± 0.12$^{A}$ | 5.60 ± 0.13 | 6.37 ± 0.04 | 68.29 ± 0.37$^{B}$ | 32.42 ± 0.48$^{A}$ | 26.87 ± 0.06$^{B}$ | 0.226 ± 0.003$^{A}$ | 139.78 ± 0.32$^{A}$ |
| Muscle (M) | | | | | | | | | |
| Triceps brachii | 45.81 ± 0.27 | 17.81 ± 0.12$^{B}$ | 4.81 ± 0.13$^{B}$ | 6.41 ± 0.04 | 80.86 ± 0.37$^{A}$ | 27.63 ± 0.48 | 27.16 ± 0.06$^{B}$ | 0.149 ± 0.003$^{B}$ | 102.27 ± 0.32$^{B}$ |
| Gluteus bíceps | 44.81 ± 0.27 | 19.43 ± 0.12$^{A}$ | 6.15 ± 0.13$^{A}$ | 6.28 ± 0.04 | 71.20 ± 0.37$^{B}$ | 29.4 ± 0.48 | 33.54 ± 0.06$^{A}$ | 0.187 ± 0.003$^{A}$ | 152.55 ± 0.32$^{A}$ |
| Supplementation (S) | | | | | | | | | |
| 0 % BW | 46.73 ± 0.27$^{A}$ | 18.47 ± 0.12 | 6.40 ± 0.13$^{A}$ | 6.26 ± 0.04 | 75.85 ± 0.37 | 26.87 ± 0.48$^{B}$ | 29.42 ± 0.06 | 0.161 ± 0.003 | 136.94 ± 0.32$^{A}$ |
| 0.7 % BW | 43.89 ± 0.27$^{B}$ | 18.78 ± 0.12 | 4.57 ± 0.13$^{B}$ | 6.43 ± 0.04 | 76.22 ± 0.37 | 30.17 ± 0.48$^{A}$ | 31.18 ± 0.06 | 0.174 ± 0.003 | 117.88 ± 0.32$^{B}$ |
| Sources of variation | Significance level | | | | | | | | |
| P-value AP | 0.5255 | 0.0166 | 0.5226 | 0.6869 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0016 |
| P-value M | 0.2834 | 0.0014 | 0.0001 | 0.3110 | 0.0001 | 0.1699 | 0.0006 | 0.0003 | 0.0001 |
| P-value S | 0.0047 | 0.4985 | 0.0001 | 0.1953 | 0.7889 | 0.0149 | 0.2845 | 0.0652 | 0.0118 |
| P-value AP × M | 0.2371 | 0.1326 | 0.009 | 0.9841 | 0.0002 | 0.0001 | 0.0302 | 0.0001 | 0.0253 |
| P-value AP × S | 0.8678 | 0.3157 | 0.0001 | 0.2211 | 0.2311 | 0.4506 | 0.2013 | 0.0043 | 0.1184 |
| [1]CV (%) | 5.73 | 6.92 | 8.97 | 5.59 | 5.04 | 12.55 | 5.08 | 6.32 | 5.62 |

Means with equal uppercase letters in column do not differ by Tukey test (P>0.05). [1]Coefficient of variation (%).

The lipid oxidation increased in both muscles after time of aging, but in supplemented animals it increased less than in non-supplemented animals, suggesting that supplementation works as an antioxidant, which reduces the formation of metal ions which catalyze lipid oxidation.

Table 4. Deployment of muscle interactions-time of aging (TA) for yellowness (b*) and lipid oxidation (TBARS, mg malonaldehyde/kg)

| b* | Muscle (M) | |
|---|---|---|
| Time of Aging (TA) | Triceps brachii | Gluteus biceps |
| Fresh | $5.21 \pm 0.13^{Aa}$ | $5.51 \pm 0.13^{Ab}$ |
| Seven days | $4.41 \pm 0.19^{Ab}$ | $6.80 \pm 0.19^{Aa}$ |
| TBARS | Muscle (M) | |
| Time of Aging (TA) | Triceps brachii | gluteus biceps |
| Fresh | $0.137 \pm 0.003^{Ba}$ | $0.083 \pm 0.003^{Bb}$ |
| Seven days | $0.254 \pm 0.007^{Ab}$ | $0.288 \pm 0.007^{Aa}$ |

Means with equal uppercase (column) and lowercase (line) letters do not differ by Tukey test (P>0.05)

Table 5. Deployment of the interaction between time of aging (TA) and supplementation for yellowness (b*) and lipid oxidation (TBARS, mg malonaldehyde/kg)

| b* | Supplementation (S) | |
|---|---|---|
| Time of Aging (TA) | 0% | 0.7% |
| Fresh | $5.41 \pm 0.09^{Ba}$ | $5.32 \pm 0.09^{Aa}$ |
| Seven days | $7.39 \pm 0.11^{Aa}$ | $3.81 \pm 0.11^{Bb}$ |
| TBARS | Supplementation (S) | |
| Time of Aging (TA) | 0% | 0.7% |
| Fresh | $0.134 \pm 0.005^{Ba}$ | $0.086 \pm 0.005^{Bb}$ |
| Seven days | $0.227 \pm 0.009^{Aa}$ | $0.215 \pm 0.009^{Ab}$ |

Means with equal uppercase (column) and lowercase (line) do not differ by Tukey test (P>0.05). MDA-malonaldehyde.

It was noted that the time of aging process increased CL (P = 0.0001) and decreased the WHC (P = 0.0001) for both muscles (Table 6). However, the aging process decreased the CL in greater intensity for the triceps brachii muscle than the gluteus biceps compared to the control, but the WHC for the triceps brachii was higher than gluteus biceps.

The MFI increased 17.7% (P = 0.0253) and the SF decreased 20.6% after the time of aging for both muscles (P = 0.0302). The gluteus biceps muscle showed higher MFI than triceps brachii in fresh and aged meat, and the triceps brachii muscle showed lower SF than the other muscle (Table 7).

Table 6. Deployment of muscle interactions-time of aging (TA) for cooking loss (CL,%) and water holding capacity (WHC,%)

| CL (%) | Muscle (M) | |
|---|---|---|
| Time of Aging (TA) | Tríceps brachii | Gluteus bíceps |
| Fresh | $20.27 \pm 0.32^{Bb}$ | $28.94 \pm 0.32^{Aa}$ |
| Seven days | $34.97 \pm 0.25^{Aa}$ | $29.88 \pm 0.25^{Ab}$ |
| WHC (%) | Muscle (M) | |
| Time of Aging (TA) | Tríceps brachii | Gluteus bíceps |
| Fresh | $85.65 \pm 0.40^{Aa}$ | $81.90 \pm 0.40^{Aa}$ |
| Seven days | $76.08 \pm 0.21^{Ba}$ | $60.50 \pm 0.21^{Bb}$ |

Means with equal uppercase (column) and lowercase (line) do not differ by Tukey test (P>0.05).

Table 7. Deployment of muscle interactions-aging period (AP) for myofibrillar fragmentation index (MFI) and shear force (SF, N)

| MFI<br>Aging Period (AP) | Muscle (M) | |
|---|---|---|
| | Tríceps brachii | Gluteus bíceps |
| Fresh | $81.54 \pm 0.61^{Bb}$ | $148.53 \pm 0.61^{Aa}$ |
| Seven days | $122.99 \pm 0.41^{Ab}$ | $156.58 \pm 0.41^{Aa}$ |
| SF<br>Aging Period (AP) | Muscle (M) | |
| | Tríceps brachii | Gluteus bíceps |
| Fresh | $28.85 \pm 0.11^{Ab}$ | $38.83 \pm 0.11^{Aa}$ |
| Seven days | $25.55 \pm 0.09^{Aa}$ | $28.15 \pm 0.09^{Ba}$ |

Means with equal uppercase (column) and lowercase (line) do not differ by Tukey test (P>0.05).

The Supplementation increased lipid oxidation, decreasing the shelf life in both muscles. The aging process improved the tenderness in both muscles by about 11% and 27% in triceps brachii and gluteus biceps, respectively.

**Discussion**

Meat from supplemented animals with 0.7% BW, presented lower lightness (L*) (43.89) than the control group (46.73). The redness was higher for the gluteus biceps (19.43) than the triceps brachii muscle (17.81) and increased during the time of aging from 18.04 to 19.21 (Table 3). Possibly the gluteus biceps muscle presented higher concentrations of myoglobin, a pigment that gives red color to meat. More reddish meat tends to attract more attention from consumers at the time of purchase, as it is interpreted

as fresh meat, which may be attributed to the predominant fiber type in the muscles. The glycolytic fibers have larger diameter and lighter appearance (white), while the oxidative and oxidative-glycolytic fibers have smaller diameter and reddish appearance, due to higher presence of myoglobin (RAMOS and GOMIDE 2007). During the aging period redness increased in both muscles, depending on the change in the oxidation-reduction of iron ions. According OLIVO and OLIVO (2005), when the iron ion is reduced (Fe2+), it can bind to water molecules or oxygen, which influences the chemical state of myoglobin, depending on the valence of the iron ion. In vacuum-packed meat in the absence of oxygen, the Fe2+ ion binds to water, moving from myoglobin to deoxymyoglobin with a dark red color.

The time of the aging process influenced the yellowness of the meat between the two muscles studied, 6.80 for gluteus biceps and 4.41 in triceps brachii (Table 4). For PEARCE et al. (2005) consumers prefer the more reddish meat, and the increased intensity of yellow (b*), may reduce consumer acceptability. Thus, the muscle triceps brachii would have greater demand at the time of purchase.

The difference between the muscles can be attributed to the greater movement of the *gluteus biceps*, because low lipid stability is related to high metal ion content, catalyzing peroxidation, according to FUKOZAWA and FUJI (1992) (Table 4). Animals that move more have higher concentrations of iron ions and lipid oxidation capacity in their muscles (O'BRIEN et al., 1992). The averages for this variable, for up to 14 days of aging, are below the values that may be noticeable to consumers (Table 5). O'NEILL et al., (1998) showed that TBARS values above 2.0 mg malonaldehyde/kg (MDA) of meat are perceptible by the consumer, thus, even meat aged for up to 14 days can be consumed without causing any health problems.

The triceps brachii had lower shear force than the gluteos biceps muscle, probably suffering from the stronger action of proteolytic enzymes (calpain I and II) that promote degradation (breakdown), denaturation and disintegration of the compact muscle fibers during rigor mortis. This process improves up to 20% tenderness, facilitates cooking loss, translocation of water to the surface, increases tenderness, the MFI, the CL and decreased the WHC during aging (Tables 6 and 7). These enzymes, calpain I and II, may be active for up to 21 days. The rate of degradation of muscle fibers by the action of proteolytic enzymes depends on the time of aging and the level of compression of the resulting myofibrils of rigor mortis. The variation in aged meat can be explained by the increase in insoluble conjunctive tissue (collagen) and the intensity and extent of myofibrillar proteolysis (DRANSFIELD et al., 1984; KOOHMARAIE et al., 2002; and HUFF-LONERGAN and LONERGAN 2005).

Supplementation decreased lipid oxidation, increasing the shelf life in both muscles (Table 5). The aging process improved the tenderness in both muscles by about 11% and 27% in the triceps brachii and gluteus biceps, respectively (Table 7).

In this study, the triceps brachii and gluteus biceps muscles may be considered to be tender. According to CULLER et al., (1978) and CEZAR and SOUSA (2007), meats with MFI higher than 60 and SF lower than 35.6 N may be regarded as tender (Table 7).

## Conclusions

Supplementation implies an increase in production costs, but its use provides quantitative and qualitative characteristics favorable for the product, aiming to satisfy the consumer market. The supplementation decreased the shelf life, increasing the lipid oxidation during the time of aging and affected the lighttness and the hue of yellow, which may disturb consumers' intention to purchase.

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## References

BARROS, C. S., A. L. G. MONTEIRO, C. H. E. C. POLI, J. R. DITTRICH, J. R. F. CANZIANI, M. A. M. FERNANDES (2009): Economic return of sheep production on pasture and in feedlot (Rentabilidade da produção de ovinos de corte em pastagem e em confinamento). R. Bras. Zootecn. 38, 2270-2279 (in Portuguese).

DOI: 10.1590/S1516-35982009001100029

BORGES, A. S., J. F. F. ZAPATA, D. S. GARRUTI, M. C. P. RODRIGUES, E. R. FREITAS, A. L. F. PEREIRA (2006): Instrumental and sensorial assessment of tenderness and juiciness in goat meat (Medições instrumentais e sensoriais de dureza e suculência na carne caprina). Ciência Tecnol. Alime. 26, 891-896 (in Portuguese).

DOI: 10.1590/S0101-20612006000400028

CEZAR, M. F., W. H. SOUSA (2007): Sheep and goat carcasses: obtaining, evaluation and classification (Carcaças ovinas e caprinas: obtenção, avaliação e classificação). Agropecuária Tropical 1, p. 232 (in Portuguese).

CULLER, R. D., F. C. Jr. PARRISH, G. C. SMITH, H. R. CROSS (1978): Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. J. Food Sci. 43, 1177-1180.

DOI: 10.1111/j.1365-2621.1978.tb15263.x

DRANSFIELD, E., D. J. ETHERINGTON, M. A. J. TAYLOR (1984): Modelling *post-mortem* tenderisation - ii: enzyme changes during storage of electrically stimulated and non- stimulated Beef Meat Sci. 31, 75-84.

DOI: 10.1016/0309-1740(92)90073-D

FUKOZAWA, K., T. FUJI (1992): Peroxide dependent and independent lipid peroxidation site-specific mechanism of initiation by chelated iron inhibition by a-tocopherol. Lipids 27, 227-233.

DOI: 10.1007/BF02536183

GORNALL, A. G., C. J. BARDAWILL, M. M. DAVID (1949): Determination of serum protein by means of the biuret reaction. J. Biol. Chem. 177, 751-766.

HAMM, R. (1960): Biochemistry of meat hydration. Adv. Food Res. 10, 335-443.

HUFF-LONERGAN, E., S. M. LONERGAN (2005): Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. Meat Sci. 71, 194-204.

DOI: 10.1016/j.meatsci.2005.04.022

KOOHMARAIE. M., M. P. KENT, S. D. SHACKELFORD, E. VEISETH, T. L. WHEELER. (2002): Meat tenderness and muscle growth: is there any relationship? Meat Sci. 62, 345-352. DOI: 10.1016/S0309-1740(02)00127-4

KUBOTA, E. H., R. OLIVO, M. SHIMOKOMAKI (1993): Aging of meat: an enzymatic process (Maturação da carne: um processo enzimático). Revista Nacional da Carne 18, 12-15 (in Portuguese).

LAWRIE, R. A. (1985): Meat Science. 5ed Oxford, England: Pergamin, Cap. 5, pp. 74-91.

MOLENTO, M. B., C. TASCA, A. GALLO, M. FERREIRA, R. BONONI, E. STECCA (2004): Famacha method as an individual clinical parameter of *Haemonchus contortus* infection in small ruminants (Método Famacha como parâmetro clínico individual de infecção por *Haemonchus contortus* em pequenos ruminantes). Cienc. Rural 34, 1139-1145 (in Portuguese).

DOI: 10.1590/S0103-84782004000400027

NETTO, E. T., F. A. TORRES (2008): Sheep meat and heart (A carne ovina e o coração). Available at: http://www.farmpoint.com.br/cadeia-produtiva/saude-qualidade-de-vida/a-carne-ovina-e-o-coracao-44637n.aspx. Accessed on: December, 2012 (in Portuguese).

O'BRIEN, P. J., H. SHEN, L. J. MCCUTCHEON, M. O'GRADY, P. J. BYRNE, H. W. FERGUSSON, M. S. MIRSALIMI, R. J. JULIAN, J. M. SARGEANT, R. R. TREMBLAY (1992): Rapid, simple and sensitive micro assay for skeletal and cardiac muscle myoglobin and hemoglobin: use in various animals: functional role of myohemoproteins. Mol. Cell Biochem. 112, 45-52.

DOI: 10.1007/BF00229642

OLIVO, R., N. OLIVO (2005): The World of Meat, Science, Technology and Market (O mundo das carnes, Ciência, Tecnologia e Mercado), Criciúma, 21st ed., p. 211.

O'NEILL, L. M., K. GALVIN, P. A. MORRISSEY, D. J. BUCKLEY (1998): Comparison of effects of dietary olive oil, tallow and vitamin E on the quality of broiler meat products. Brit. Poultry Sci. 39, 365-371.

DOI: 10.1080/00071669888917

PEARCE, K. L., D. G. MASTERS, R. H. JACOB, G. SMITH, D. W. PETHICK (2005): Plasma and tissue a-tocopherol concentrations and meat colour stability in sheep grazing saltbush (*Atriplex* spp.). Aust. J. Agr. Res. 56, 663-672.

DOI: 10.1071/AR05001

PUGA, D. M. U., C. J. C. CONTRERAS, M. R. TURNBULL (1999): Evaluation of the tenderness of beef cattle (Triceps brachii) by the methods of aging, electrical stimulation, acid injection and mechanical tenderization (Avaliação do amaciamento de carne bovina de dianteiro (Triceps brachii) pelos métodos de maturação, estimulação elétrica, injeção de ácidos e tenderização mecânica). Ciência Tecnol. Alime. 19, 1-10 (in Portuguese).

DOI: 10.1590/S0101-20611999000100016

RAMOS E. M., L. A. M. GOMIDE (2007): Evaluation of abnormal meat: PSE and DFD conditions. In "Evaluation of Meat Quality: Fundamentals and Methodologies" (Avaliação de carnes anormais: condições PSE e DFD. In: Avaliação da qualidade de carnes: Fundamentos e metodologias). (Ramos, E. M., L. A. M. Gomide, Eds). Federal University of Viçosa: Viçosa, Minas Gerais, Brazil, pp. 531-575 (in Portuguese).

SAS (2002) SAS INSTITUTe User's Guide: Statistics. Lect. Notes Comput. Sc.

VEISETH, E., M. KOOHMARAIE (2001): Effect of extraction buffer on estimating calpain and calpastatin activity in post mortem ovine muscle. Meat Sci. 57, 325-329.

DOI: 10.1016/S0309-1740(00)00109-1

VYNCKE, B. W. (1970): Direct determination of the thiobarbituric acid value in trichloracetic acid extracts of fish as a measure of oxidative rancidity. Fett. Wiss. Technol. 72, 1084-1087.

DOI: 10.1002/lipi.19700721218

VOLTOLINI, T. V., F. A. P. SANTOS, J. C. MARTINEZ, H. IMAIZUMI, A. V. PIRES, M. A. PENATI (2008): Metabolizable protein supply according to the NRC (2001) for dairy cows grazing Elephant grass. Sci. Agr. 65, 130-138.

DOI: 10.1590/S0103-90162008000200004

WHEELER, T. L., S. D. SHACKELFORD, M. KOOHMARAIE (2005): Shear Force Procedures For Meat Tenderness Measurement. United States Department of Agriculture (USDA), Clay Center, NE, (A. R. Service, Trans.). p. 7.

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**SAŽETAK**

Mišići triceps brachii i gluteus biceps analizirani su kako bi se ocijenio učinak dodataka prehrani na zrenje janjećeg mesa. Ukupno 48 janjadi pasmine Santa Inês imalo je početnu prosječnu tjelesnu masu 15 kg, a nakon pet mjeseci različite prehrane prosječna je tjelesna masa bila 32 kg. Životinje su razmještene na 16 pašnjaka s rezidualnim indeksom lisne površine 2,6, pod jednakim uvjetima, pri čemu su 24 životinje dobivale dodatke prehrani. Uzevši u obzir indeks lisne površine te dodatke hrani formirano je osam skupina koje su uspoređene faktorijalnom analizom. Kriterij za klanje bila je dob životinja. Povećana oksidacija lipida ustanovljena je nakon sedam dana zrenja mesa mišića triceps brachii i gluteus biceps. Vrijednosti gubitaka nastalih kuhanjem i sposobnost zadržavanja vode povećale su se s duljinom zrenja te su u m. gluteus biceps bile više, 29,40 % odnosno 71,30 %. Dodaci prehrani podrazumijevaju povećane troškove proizvodnje, ali njihova uporaba omogućuje bolje kvantitativne i kvalitativne značajke, s ciljem da se zadovolji tržište. Dodaci prehrani skraćuju rok trajanja mesa, povećavaju oksidaciju lipida za vrijeme zrenja te utječu na svjetloću i žutilo zbog čega potrošači mogu dvojiti pri kupnji mesa.

**Ključne riječi:** oksidacija lipida, indeks fragmentacije mišićnih vlakana, crvenilo, rok trajanja, smična sila, nježnost, žutilo