

Effect of pre and post-slaughter processes on meat characteristics of Santa Ines ewes discarded due to age

Efeito de processos de pré e pós-abate sobre características da carne de ovelhas da raça Santa Inês, descartadas por idade

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Abstract

The effects of body condition recovery (BC), carcass electrical stimulation (ES), aging time (AT 7 - 14 days), and calcium chloride injection on the meat characteristics of Santa Inês ewes (± 5 years old) slaughtered immediately after weaning or after the body condition recovery period were studied. The carcass temperature, pH, shear force (SF), cooking loss (CL), meat color (L^* , a^* , b^*), and meat tenderness were evaluated. A completely randomized design in a $2 \times 2 \times 2 \times 3$ (BC \times ES \times CaCl₂ \times AT) factorial arrangement was used, and the sensory tenderness data were analyzed using the table of Minimum Number of Correct Answers for the Duo-Trio test. The body condition recovery reduces the shear force in 8%, increasing their tenderness. Electrical stimulation reduced the shear force (24%) and did not change the other parameters. The aging time (7 or 14 days) decreased the shear force (18-26%), effect that was enhanced by electrical stimulation, and it darkened the meat reducing lightness (L^*) and increasing yellowness (b^*). The treatment with CaCl₂ was the most effective in tenderizing meat by reducing the shear force (35%); increasing the cooking loss (4.5%); and increasing L^* and b^* lightening the meat. The sensory evaluation of tenderness corroborates the findings of the experimental evaluation regarding the effect of the treatment with CaCl₂ on the meat quality improvement. It was concluded that the treatments improve meat characteristics achieving better results when applied together.

Keywords: ewes; slaughter; tenderness; cooking loss; color; sensory evaluation.

Resumo

Estudaram-se os efeitos da recuperação da condição corporal (CC), da estimulação elétrica (EE), da maturação (M 7-14 dias) e da infusão de CaCl₂ sobre as características da carne de ovelhas Santa Inês (cerca de 5 anos de idade), abatidas ao desmame ou após o período de recuperação pós-desmame. Avaliaram-se a temperatura e o pH de carcaça, e a força de cisalhamento (FC); a perda por cocção (PC); a cor (L^* , a^* e b^*), e a maciez da carne. Utilizou-se delineamento inteiramente casualizado, em esquema fatorial $2 \times 2 \times 2 \times 3$ (CC \times EE \times CaCl₂ \times M); para a análise dos dados sensoriais de maciez, utilizou-se a tabela de Número Mínimo de Respostas Corretas para o teste Duo-Trio. A recuperação da condição corporal diminuiu a força de cisalhamento (8%), aumentando a sua maciez. A estimulação elétrica diminuiu a força de cisalhamento (24%) e não alterou os demais parâmetros avaliados. A maturação (7 ou 14 dias) diminuiu a força de cisalhamento (18-26%), efeito acentuado pela estimulação elétrica, e escureceu a carne, diminuindo a luminosidade (L^*) e acentuando b^* (amarelo). O tratamento com infusão de CaCl₂ foi mais efetivo no amaciamento da carne, reduzindo a força de cisalhamento (35%), aumentando a perda por cocção (4,5%) e os valores L^* e b^* , clareando a carne. A avaliação sensorial da maciez corroborou a avaliação instrumental referente ao efeito do CaCl₂ na melhoria da qualidade da carne. Conclui-se que os tratamentos melhoram as características da carne, com melhores resultados quando aplicados conjuntamente.

Palavras-chave: ovelhas; abate; maciez, perda por cocção, cor, avaliação sensorial.

1 Introduction

In the sheep meat production systems, old ewes are used one last time for breeding and then are sent to slaughter. These animals are slaughtered immediately after weaning (CUNHA et al., 2008) when they are skinny and show worn out signs due to from spooliation during the lactation period.

The meat produced under such conditions has poor quality, dark color, lower palatability and tenderness, and therefore is devalued on the market (RODA et al., 1998).

However, soon after weaning, the ewes keep for a short time the hormonal and physiological conditions typical of the end of lactation period, which lead to the maximum nutrient use. During this period, if the nutritional conditions are favorable, the ewes enter a positive nutrient balance stage and quickly improve their body condition with pronounced weight gain and recovery of fat and muscle mass lost during lactation. This is the "compensatory weight gain" (RESTLE et al., 2001). Feeding ewes

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low cost diets after weaning, based on high energy levels, can be an alternative to improve meat quality and produce higher yield (RODA et al., 1998).

The carcass of animals in good body conditions at the time of slaughter has a well-developed and uniform fat covering layer. This is a fundamental quality characteristic for carcasses to decrease yield losses due to excessive loss of moisture from the outer layer preventing meat darkening and slowing the speed and lowering the intensity of meat temperature decrease avoiding the occurrence of “cold shortening” (FELÍCIO, 1997).

In addition to the pre-slaughter body conditions adequacy, some post-slaughter procedures such as carcass electrical stimulation, meat aging, and calcium chloride infusion may also be used to improve the sensory characteristics of meat, mainly tenderness focusing on a greater consumer acceptance and product appreciation (LUCHIARI FILHO, 2000).

Electrical stimulation of the carcass after bleeding increases meat tenderness, and today it is a widely used process in bovine slaughterhouses (FELÍCIO, 1997). This process affects sheep carcass improving meat quality by increasing tenderness and color lightness, and it represents an important tool for maintaining uniformity and meat quality. The positive effects of this procedure, performed immediately after slaughter, are due mainly to the greater bleeding efficiency, to the acceleration of the pH decrease, and to the disruption of the myofibrillar structure (TOOHEY; PEARCE, 2008).

The aging process consist in keeping the meat vacuum packed and refrigerated at a temperature around 0 °C for periods between 7 and 28 days after slaughter and after resolution of rigor mortis (FELÍCIO, 1997), which may increase meat tenderness. Under these conditions, meat tenderization is the result of the natural action of the calpain proteolytic system (KOOHMARAIE et al., 1991).

The infusion of carcasses with a solution of calcium chloride is another meat tenderization process based on enhancement of the natural activity of the calcium-dependent meat enzymes of the calpain system. Calpain I or μ -calpain requires low levels of calcium for activation (1-10 mM), while calpain II or m-calpain requires high levels of free calcium (50 to 70 mM). These amounts are far greater than the those found naturally in meat. Infusion of calcium chloride increases calcium concentration and enhances proteolysis during aging affecting the texture of the meat reducing the shear force (HEINEMANN; PINTO, 2003).

Studies that evaluate cheap and easily applicable processes in pre- and post-slaughter can increase yield and improve carcass characteristics and meat quality of old ewes. They may yet result in the development of rearing practices and propose slaughtering techniques and meat processing which can help increase productivity and profits adding value to the product while offering a more healthy and tasty meat to the consumer.

The higher market demand and higher product quality can result in higher gains to the producer contributing to the socio-economic viability of small farms involved in sheep

rearing, especially those with familiar characteristics (SANTOS; BUENO; CUNHA, 2007).

This study was carried out to evaluate the effects of body condition recovery, carcass electrical stimulation, aging time, and effects of calcium chloride injection on the meat characteristics of old Santa Inês ewes slaughtered immediately after weaning or after the body condition recovery period as a way to increase productivity and improve meat quality.

2 Materials and methods

This study was conducted at the Sheep Unity of the Instituto de Zootecnia (Nova Odessa/SP), from February through May 2009 with the approval of the Institute Ethics Committee under protocol number 70/2009.

Initially, 50 Santa Inês ewes five to six years old weighing 50 to 60 kg were kept in a dry lot feeding program until weaning, when 24 single-lambing ewes were selected for weight and body condition (BC) with a score between 1.5 and 2 (thin condition).

Half the ewes were sent to slaughter soon after weaning, while the others were kept in pastures of Aruana grass (*Panicum maximum*, cv. Aruana), on a rotational grazing system with flexible stocking rate and ad libitum daily feeding of roughage mixture of 70% of chopped Guaçu grass (*Pennisetum purpureum* Schum. cv. Guaçu) and 30% of ground whole-plant dry corn (44.2% DM, 69.3% TDN and 3.9% CP) for 30 to 45 days after weaning to recover the body condition until reaching a score between 3 and 3.5 (fat condition), when they were slaughtered.

The animals were fasted (water access only) for 24 hours and slaughtered according the RIISPOA rules (BRASIL, 1997). The pH and carcass temperature were measured to monitor the rigor mortis process using a portable potentiometer (HANNA Instruments Inc.) with a penetration glass electrode combined with thermocouple (°C and pH). The measurements were performed after bleeding and 24 hours after slaughter.

Immediately after bleeding, half of the ewes of each body condition, in random alternating order, were submitted to low-voltage electrical stimulation (ES) using a Jarvis stimulator (BV80). Each carcass was stimulated for 17 seconds, alternating pulse stimulation for 5 seconds and 1 second without stimulation, using electrical current of 21 V, 60 Hz, and 13 mA.

The carcasses were stored at initial temperature of ± 5 °C for 6 hours, and then at ± 1 °C for 24 hours. They were halved and the *Biceps femoris* muscle was removed from each half carcass. The right half carcass muscle was not treated (control), and that of left half carcass was injected with a 0.2 M calcium chloride solution (CaCl₂ 10% by sample weight). After 10 minutes, each muscle (treated and control) was divided into three sub-samples and randomly assigned to different aging times (AT): 0, 7, and 14 days.

The muscle sub-samples were packed and kept refrigerated (± 1 °C) totaling 6 replicates per factor studied (Body Condition X Carcass Electric Stimulation X CaCl₂ infusion X Aging Time).

The meat sub-samples for the aging treatments of 7 and 14 days were vacuum packed in suitable plastic containers, and those without aging were packed in polyethylene bags without vacuum.

After 48 hours of slaughter, the non-aged meat samples were analyzed to determine the parameters of shear force (SF), cooking weight loss (CL), color parameters (L^* , a^* , b^*), and sensory evaluation test of tenderness. The aged samples were analyzed after 7 and 14 days of aging.

In each analysis series, the meat sub-samples were divided into 3 portions ($\sim 3.0 \times 3.0 \times 2.0$ cm), weighed, and cooked in an oven preheated to 170 °C until they reached the internal temperature of 70 °C, monitored using a digital thermometer (Delta OHM, model HD9218). The meat portions were then cooled to ambient temperature and re-weighed. The cooking weight loss was calculated by the difference between the weighing before and after cooking, and the values were expressed as percentage (%) of loss. For the statistical analysis, it was considered the mean value of the 3 portions.

Subsequently, two sub-samples were taken from each portion for tenderness assessment using shear force measurements by means of a texturometer equipped with Warner-Bratzler shearing device. The sub-samples consisted of cylinders of

cooked meat extracted manually from the meat samples, previously used in the cooking loss evaluation, using a metal cylinder of 1.27 cm in diameter along the full length of the muscle fibers.

For the purposes of statistical analysis, the mean value of four samples was considered disregarding the two extreme values.

The sensory evaluations of *B. femoris* samples were conducted right after slaughtering (non-aged samples) and after 7 or 14 days (aged samples).

The evaluations were performed using the Duo-trio test on a varying number of non-trained judges in each phase resulting in a total of 70 responses for the non-aged meat samples; 55 responses for the 7-day samples and 52 responses for the 14-day samples.

Before each evaluation session, the evaluators received a test card (Figure 1) and the test instructions. They were instructed to fill in the card identifying which coded sample is similar to the reference sample in terms of feeling of tenderness and which of the two samples was the most tender (as observation).

The same meat samples used for the evaluation of cooking weight loss were also used for sensory evaluation, and they

TEST OF DIFFERENCE

PLEASE RECOGNIZE WHICH IS SIMILAR TO THE STANDARD SAMPLE

You will receive three samples, one standard and two treatments.
Please taste the standard sample and then the samples of the treatments.
When finished, choose which sample is similar to the standard.

| | | |
|------------------------|-------------------|-------------------|
| Standard Sample | Sample 201 | Sample 210 |
|------------------------|-------------------|-------------------|

Similar to the Standard: _____

PLEASE TICK THE SOFTER SAMPLE:

| | |
|-------------------|-------------------|
| Sample 201 | Sample 210 |
|-------------------|-------------------|

Date: ____/____/____

Figure 1. Card used in the Sensory Evaluation panels.

consisted of regular pieces of meat, of approximately 3 cm thick, which were offered to the judges at the temperature of 45 °C.

The evaluation of the meat color parameters was performed using the CIE L* a* b* system using a Minolta colorimeter (Chroma Meter CR-300) and considering the average value of 3 readings at separated points of each sub-sample of the muscle.

The experimental design used to analyze the data of meat characteristics (Shear Force, Cooking Loss, and Color Parameters - CIE L* a* b*) was a completely randomized factorial design in 2 × 2 × 2 × 3 (Body Condition X Carcass Electric Stimulation X CaCl₂ infusion X Aging Time) using the Proc Mixed procedure of SAS (STATISTICAL..., 1998). To analyze the data of the sensory evaluation of tenderness, the Duo-Trio Test was used on a varied number of non-trained judges considering the number of correct answers according to the table of minimum number of correct selections to establish significance for the Duo-Trio test (ROESSLER et al., 1978).

3 Results and discussion

The temperature and pH of the ewe carcasses decreased during cooling during the normal process of converting muscle to meat, *i.e.*, the temperature ranged from 38.10-39.95 °C (after bleeding) to 1.47-1.96 °C (24 hours after slaughter) and the pH from 6.50-6.85 to 5.76-5.96, respectively.

3.1 Shear Force (SF)

The SF values observed for the ham samples (*Biceps femoris* muscle) are presented in Table 1, and the data analysis showed effects ($p < 0.01$) of all the treatments, resulting in lower values of SF, indicating that these processes improved the ewe meat tenderness.

The recovery of BC was effective in reducing the SF value by up to 7.94% with mean values of 3.52 kgf.cm⁻¹ for lean ewes and 3.24 kgf.cm⁻¹ for the fatter ones. Both values indicate very tender meat, according to Boleman et al. (1997), who proposed the limit 2.3-3.6 kgf.cm⁻¹ for very tender meat; 3.7-4.0 kgf.cm⁻¹

for tender meat; 4.1-5.8 kgf.cm⁻¹ for moderately tender meat, and 5.9-7.2 kgf.cm⁻¹ for a less tender meat.

Similar results of the BC effect on meat quality were obtained by Fernandes et al. (2008), who observed SF values of 3.29 kgf.cm⁻¹ in pasture-raised and reraised lambs and slaughtered at a later age (low BC) and values of 1.95 kgf.cm⁻¹ in non-weaned feedlot lambs until slaughter (high BC).

Other authors (PINHEIRO; JORGE, 2008) measured SF in the *Triceps brachii* muscle of lambs and obtained a very tender meat with values from 1.02 to 1.03 kgf.cm⁻¹.

Carcass electrical stimulation also proved an effective process to increase meat tenderness, which was evidenced by the reduction of SF values from 3.85 kgf.cm⁻¹ in non-stimulated meat to 2.91 kgf.cm⁻¹ in stimulated meat with a reduction effect of about 24.4%.

The effectiveness in reducing SF in sheep meat has been confirmed in several studies (KOOHMARAIE et al., 1988; KOOHMARAIE; DOUMIT; WHEELER; 1996; DUCKETT et al., 1998; WHEELER; KOOHMARAIE, 1999).

Similar results (DEVINE et al., 2001) were observed with high-voltage ES in sheep, whereas Davel et al. (2003) did not find significant effect on the SF of lamb meat obtaining values of 3.84 and 3.32 kgf.cm⁻¹ for non-stimulated and stimulated carcasses, respectively, when using low-voltage ES.

Martin et al. (2006) didn't observe any effect of ES using medium voltage (400 mA, 300 V, for 35 seconds and 14 pulses/s) in lambs observing SF values of 3.84 kgf.cm⁻¹ for not ES meat and of 4.03 kgf.cm⁻¹ for the stimulated ones.

The values of shear force usually differ within and between institutions because of the protocol, the implementation of the protocol, and the equipment variation of the (WHEELER; SHACKELFORD; KOOHMARAIE, 1996).

Aging meat for 7 or 14 days was effective ($p < 0.01$) on meat SF reduction. The analysis of the data obtained in this study indicates a reduction in the value of FS from 3.92 kgf.cm⁻¹

Table 1. Effect of body condition, carcass electrical stimulation, aging time, and meat treatment with a solution 2 M of CaCl₂ on the shear force of *Biceps femoris* muscle of Santa Ines ewes (± 5 years old).

| Body condition | Electrical stimulation | Aging time (days) | Shear force (kgf.cm ⁻¹) | | | |
|--------------------------------|-------------------------------|-------------------|-------------------------------------|-------|-----------------------------|-------|
| | | | Ham* without CaCl ₂ | CV% | Ham* with CaCl ₂ | CV% |
| Lean condition ⁽¹²⁾ | Not Stimulated ⁽⁶⁾ | 0 ⁽⁶⁾ | 5.39 ± 0.56 ^{aA} | 10.39 | 3.62 ± 0.73 ^{aB} | 20.17 |
| | | 7 ⁽⁶⁾ | 4.77 ± 0.72 ^{bA} | 15.09 | 3.03 ± 0.40 ^{cB} | 13.20 |
| | | 14 ⁽⁶⁾ | 4.46 ± 0.53 ^{cA} | 11.88 | 2.80 ± 0.22 ^{dB} | 7.86 |
| | Stimulated ⁽⁶⁾ | 0 ⁽⁶⁾ | 4.00 ± 0.19 ^{eA} | 4.75 | 2.63 ± 0.52 ^{dB} | 19.77 |
| | | 7 ⁽⁶⁾ | 3.72 ± 0.36 ^{fA} | 9.68 | 2.27 ± 0.24 ^{eB} | 10.57 |
| | | 14 ⁽⁶⁾ | 3.61 ± 0.23 ^{fA} | 6.37 | 1.96 ± 0.19 ^{fB} | 9.69 |
| Fat condition ⁽¹²⁾ | Not Stimulated ⁽⁶⁾ | 0 ⁽⁶⁾ | 5.24 ± 0.56 ^{aA} | 10.69 | 3.44 ± 0.55 ^{bB} | 15.99 |
| | | 7 ⁽⁶⁾ | 4.22 ± 0.23 ^{dA} | 5.45 | 2.91 ± 0.15 ^{c dB} | 5.15 |
| | | 14 ⁽⁶⁾ | 4.09 ± 0.40 ^{d eA} | 9.78 | 2.27 ± 0.28 ^{eB} | 12.33 |
| | Stimulated ⁽⁶⁾ | 0 ⁽⁶⁾ | 4.16 ± 0.39 ^{d eA} | 9.38 | 2.90 ± 0.68 ^{c dB} | 23.45 |
| | | 7 ⁽⁶⁾ | 3.44 ± 0.52 ^{fA} | 15.12 | 2.19 ± 0.13 ^{eB} | 5.94 |
| | | 14 ⁽⁶⁾ | 2.19 ± 0.16 ^{gA} | 7.31 | 1.88 ± 0.10 ^{fB} | 5.32 |

(n) = Repetitions number; Mean ± standard deviation; CV % = Coefficient of variation; Different lowercase letters in columns and capital letters in rows indicate significant differences ($p < 0.01$); **Biceps femoris*.

for non-aged meat to 3.32 kgf.cm⁻¹ for meat aged for 7 days, corresponding to a reduction of 17.6% in the SF. The meat aged for 14 days showed a SF of 2.91 kgf.cm⁻¹, corresponding to a reduction of 25.7%.

Zeola et al. (2006) evaluated the effect of aging meat for 7 and 14 days in three muscles (*Biceps femoris*, *Longissimus*, and *Triceps brachii*) in lambs and observed an effect on *B. femoris*, with SF values of 2.76, 2.20 and 1.76 kgf.cm⁻¹, respectively for 0, 7, and 14 days of AT, and on the *L. dorsi*, with SF values of 3.03, 2.21 and 1.89 kgf.cm⁻¹, respectively. No difference in SF values was found for *T. brachii*, with very low values around 1.96, 1.85 and 1.30 kgf.cm⁻¹, respectively, in the three AT periods. On the other hand, Gonçalves et al. (2004) found no effect of AT on the SF and sensory tenderness in lambs.

Table 1 shows the effect of meat treated with CaCl₂ on the SF. Data analysis showed a reduction ($p < 0.01$) in the SF of treated meat compared to that of untreated meat. Evaluating the effect of this treatment only, it was observed that the injection of CaCl₂ was the most efficient process for meat tenderization; the SF reduced from 4.12 to 2.66 kgf.cm⁻¹ with an average reduction of 35.28% in the SF of meat treated compared to that of untreated meat.

Similar results found by Zeola et al. (2005) confirm the treatment effect of CaCl₂ on the SF of meat of ewes slaughtered at 50 kg live weight with values of 4.00, 3.32, and 2.95 kgf.cm⁻¹, respectively, for untreated meat, meat injected with a 0.2 M and 0.3 M solution of CaCl₂.

Later, Zeola et al. (2006) found effect of CaCl₂ treatment on the *L. dorsi* of lambs, with SF values of 2.89 and 1.86 kgf.cm⁻¹, respectively, for untreated and treated samples with 0.3 M solution of CaCl₂, i.e. a decrease of 35.64% in CF.

3.2 Cooking Loss (CL)

The mean values of CL observed in this study for the samples of ham can be seen in Table 2.

Table 2. Effect of body condition, carcass electrical stimulation, aging time and meat treatment with a solution 2 M of CaCl₂ on the cooking loss of samples of *Biceps femoris* muscle of Santa Inês ewes (± 5 years old).

| Body condition | Electrical stimulation | Aging time | Cooking loss (%) | | | |
|--------------------------------|-------------------------------|------------------------|--------------------------------|------|-----------------------------|------|
| | | | Ham* without CaCl ₂ | CV% | Ham* with CaCl ₂ | CV% |
| Thin condition ⁽¹²⁾ | Not Stimulated ⁽⁶⁾ | 0 days ⁽⁶⁾ | 20.3 ± 6.2 ^{aA} | 30.7 | 27.2 ± 6.0 ^{bB} | 22.0 |
| | | 7 days ⁽⁶⁾ | 25.6 ± 5.8 ^{bA} | 22.6 | 28.8 ± 3.8 ^{cdB} | 13.1 |
| | | 14 days ⁽⁶⁾ | 25.6 ± 6.7 ^{bA} | 26.2 | 31.0 ± 3.0 ^{dB} | 9.6 |
| | Stimulated ⁽⁶⁾ | 0 days ⁽⁶⁾ | 20.7 ± 6.6 ^{aA} | 32.0 | 26.4 ± 6.6 ^{abB} | 25.0 |
| | | 7 days ⁽⁶⁾ | 27.1 ± 7.2 ^{bA} | 26.6 | 28.0 ± 3.8 ^{bcB} | 13.6 |
| | | 14 dias ⁽⁶⁾ | 27.4 ± 7.3 ^{bA} | 26.7 | 31.2 ± 6.3 ^{dB} | 20.3 |
| Fat condition ⁽¹²⁾ | Not Stimulated ⁽⁶⁾ | 0 days ⁽⁶⁾ | 20.8 ± 7.5 ^{aA} | 38.2 | 27.9 ± 2.0 ^{bB} | 7.6 |
| | | 7 days ⁽⁶⁾ | 25.2 ± 7.1 ^{bA} | 10.8 | 28.7 ± 3.9 ^{cdB} | 14.3 |
| | | 14 days ⁽⁶⁾ | 27.5 ± 3.4 ^{bA} | 12.8 | 31.1 ± 2.5 ^{dB} | 8.4 |
| | Stimulated ⁽⁶⁾ | 0 days ⁽⁶⁾ | 19.0 ± 3.1 ^{aA} | 16.4 | 26.7 ± 2.0 ^{abB} | 7.6 |
| | | 7 days ⁽⁶⁾ | 26.5 ± 7.1 ^{bA} | 27.6 | 30.6 ± 8.7 ^{dB} | 29.7 |
| | | 14 days ⁽⁶⁾ | 26.9 ± 4.5 ^{bA} | 16.9 | 30.6 ± 1.2 ^{dB} | 3.9 |

(n) = repetitions number; Mean ± standard deviation; CV% = Coefficient of variation; Different lowercase letters in columns and capital letters in rows indicate significant differences ($p < 0.01$); *Biceps femoris.

Data analysis showed that the animal BC and carcass ES did not affect ($p > 0.05$) the CL; on the other hand, this variable was influenced ($p < 0.01$) by AT and by the treatment with CaCl₂.

The isolated effect of BC recovery showed CL mean values of 26.61% for the lower BC (lean ewes) and 25.90% for the higher BC (fat ewes).

According to Ensminger (1973), the variation in fat and moisture are the main causes of change in the composition of meat in adult sheep. Therefore, considering that the muscles of carcasses of different BC did not show differences in the amount of inter and intramuscular fat, it was concluded that the samples would also show few differences in moisture content, which would explain the similarity of CL value between them.

Evaluating the CL from lambs, rams and ewes, Pinheiro, Jorge and Souza (2009) observed differences in animal category and muscles, with average values of 66.47, 66.73, and 67.58% (*T. brachii*); 39.33, 38.32, and 46.44% (*L. lumborum*); and 39.08, 37.31 and 42.05% (*semimembranosus*), respectively; these values are substantially higher than those observed in this study. Bonagurio et al. (2003) also observed differences in CL according to animal category showing higher losses in lambs (36.12%) than in ewes (33.67%). These values were also higher than those observed in this study.

On the other hand, the meat aging process affected the CL ($p < 0.01$), and aged meat samples had greater loss than the non-aged meat samples. There was no difference between 7 and 14 days of AT. The values of CL as a function of AT were 23.16, 26.89, and 28.71%, respectively, for the period of 0, 7, and 14 days of AT.

The high CL of aged meat obtained may be partly explained by the reduced capacity to retain water (WHC) of aged muscle fibers due to the disintegration of the protein matrix found in meat depending on natural enzymatic activity, which is magnified by the aging process (BRESSAN et al., 2001).

Gonçalves et al. (2004), working with castrated rams and ewes, found no effect of AT; accordingly, Zeola et al. (2006),

evaluating CL in lambs, found no differences between the CL values, which ranged between 29.11 and 35.57% for different AT periods.

In addition, as shown in Table 2, it was found that the meat treatment with a solution of CaCl_2 affected the CL resulting in higher values of CL ($p < 0.01$) for the treated samples. The isolated effect of this treatment resulted in mean CL values of 24.02 and 28.49%, respectively, for the samples untreated and treated samples corresponding to a 4.47% more moisture loss in the treated. This difference was expected because of the methodology used in the 0.2 M CaCl_2 injection of 10% of the sample weight. The difference observed in the percentage of CL was probably due to the injected volume.

However, Zeola et al. (2005) studied the effect of the injection of 0.2 and 0.3 M CaCl_2 solutions in ewe meat samples and found no difference in the CL obtaining an average loss of 28.54%, similar to that obtained in the present study for treated meat samples.

Similarly, Pérez, Escalona and Guerrero (1998) observed that the WHC was lower for the meat treated with CaCl_2 when compared to that of the controls, which can be attributed to the increase in proteolysis that occurs in the meat treated with CaCl_2 resulting in a higher CL.

3.3 Color parameters (L^* , a^* , and b^*)

The data of the color parameters (L^* , a^* , and b^*) can be seen in Table 3, and the statistical analysis showed changes in lightness (L^* - $p < 0.01$) and in the intensity of yellow (b^* - $p < 0.05$) for BC, AT and CaCl_2 ($p < 0.01$) due to the treatments, with the exception of SF that did not change any of the parameters. On the other hand, the intensity of red (a^*) was not affected ($p > 0.05$) by any of the treatments.

In general, muscularity, amount of pigment, and therefore the amount of heme iron increase with age and level of physical

activity of the animal with higher intensity of red color (a^*) in muscles subjected to greater effort, such as *B. femoris*, which use more oxygen (SANUDO et al., 1997). This may explain the equal values for the parameter a^* (red color intensity) observed in this study and those found by Sañudo et al. (1997) evaluating the same muscle (*Biceps femoris*) in adult pasture raised animals of similar age and category.

Considering the effect of each treatment, it was found that the isolated effect of the BC recovery resulted in carcasses with lighter meat ($p < 0.01$), with L^* average values of 33.17 for the meat of ewes without BC recovery and 34.51 for those with BC recovery. According to Bressan et al. (2001), this effect could be explained by the higher fat content of meat from well-developed animals resulting in higher reflectance of incident light and hence higher values of L^* ; however, in this experiment the inter- and intra-muscular fat content did not differ markedly between the treatments.

For the a^* parameter, the mean values observed were 13.93 and 13.58 ($p > 0.05$). As for the b^* , the values of 6.67 and 6.19 differed ($p < 0.01$) respectively for the treatments with and without recovery of BC. With respect to the effect of ES carcass, although values numerically slightly higher were observed in the treatment with ES for all color parameters (L^* , a^* , and b^*), there were no statistical differences ($p > 0.05$) for this features. The mean values observed respectively for L^* , a^* , and b^* were 33.99, 13.92, and 6.45 for stimulated carcasses of 33.68, 13.58, and 6.42 for non-stimulated carcasses.

According to Kadim et al. (2009), the carcass ES results in higher value of meat lightness (L^*). Similarly, Simmons et al. (2008) argues that the ES and the resulting effects on the interaction between temperature and pH can have significant effects on meat color due to the variation in the remaining oxygen consumption rate.

The low-voltage ES of carcasses immediately after the onset of bleeding (TOOHEY; PEARCE, 2008) results in increases of up

Table 3. Effect of body condition (BC), carcass electrical stimulation (ES), aging time (AT), and meat treatment with a 2 M CaCl_2 solution on the meat color parameters (CIE L^* a^* b^*) of samples of *Biceps femoris* muscle of Santa Inês ewes (± 5 years old).

| BC | ES | AT | Color Parameters (CIE L^* a^* b^*) | | | | | | | | | | | |
|--------------------------------|--------------------|------------------------|---|------|---------------------|-------|---------------------|------|---------------------------|------|---------------------|------|---------------------|------|
| | | | Ham* without CaCl_2 | | | | | | Ham* with CaCl_2 | | | | | |
| | | | L^* | CV% | a^* | CV% | b^* | CV% | L^* | CV% | a^* | CV% | b^* | CV% |
| Thin condition ⁽¹²⁾ | Not ⁽⁶⁾ | 0 days ⁽⁶⁾ | 33.15 ^{cA} | 6.1 | 13.53 ^{aA} | 8.3 | 5.44 ^{abA} | 29.8 | 36.93 ^{eB} | 13.1 | 13.36 ^{aA} | 10.8 | 5.70 ^{aA} | 31.5 |
| | | 7 days ⁽⁶⁾ | 32.10 ^{bA} | 15.9 | 13.83 ^{aA} | 14.5 | 6.75 ^{fgA} | 24.8 | 33.72 ^{bcB} | 8.0 | 14.02 ^{aA} | 12.3 | 7.00 ^{aA} | 11.6 |
| | | 14 days ⁽⁶⁾ | 29.96 ^{aA} | 14.4 | 14.60 ^{aA} | 13.7 | 6.95 ^{gA} | 26.1 | 31.41 ^{aB} | 11.1 | 14.15 ^{aA} | 6.7 | 7.37 ^{bB} | 19.9 |
| | Yes ⁽⁶⁾ | 0 days ⁽⁶⁾ | 33.36 ^{cdA} | 7.8 | 13.72 ^{aA} | 12.7 | 5.88 ^{bcA} | 28.6 | 38.06 ^{fB} | 8.9 | 13.48 ^{aA} | 10.0 | 6.81 ^{bB} | 23.6 |
| | | 7 days ⁽⁶⁾ | 31.49 ^{bA} | 9.2 | 13.90 ^{aA} | 12.6 | 6.02 ^{cdA} | 35.0 | 33.25 ^{bB} | 9.0 | 14.37 ^{aA} | 12.0 | 7.74 ^{cB} | 25.9 |
| | | 14 days ⁽⁶⁾ | 31.54 ^{bA} | 8.1 | 14.50 ^{aA} | 19.3 | 6.41 ^{efA} | 24.6 | 33.05 ^{bB} | 8.5 | 14.26 ^{aA} | 13.9 | 7.93 ^{cB} | 19.6 |
| Fat condition ⁽¹²⁾ | Not ⁽⁶⁾ | 0 days ⁽⁶⁾ | 34.06 ^{dA} | 4.1 | 13.27 ^{aA} | 7.5 | 5.11 ^{aA} | 23.5 | 37.93 ^{fB} | 11.6 | 13.03 ^{aA} | 14.3 | 6.22 ^{cdB} | 16.1 |
| | | 7 days ⁽⁶⁾ | 33.28 ^{cdA} | 12.9 | 13.47 ^{aA} | 17.76 | 6.20 ^{deA} | 19.3 | 34.75 ^{dB} | 8.0 | 13.04 ^{aA} | 10.6 | 7.02 ^{cdB} | 13.6 |
| | | 14 days ⁽⁶⁾ | 32.26 ^{bA} | 8.3 | 13.90 ^{aA} | 15.4 | 6.40 ^{efA} | 17.7 | 34.60 ^{cdB} | 9.2 | 13.05 ^{aA} | 14.6 | 7.03 ^{cdB} | 16.2 |
| | Yes ⁽⁶⁾ | 0 days ⁽⁶⁾ | 35.10 ^{eA} | 13.7 | 13.34 ^{aA} | 14.3 | 5.75 ^{bcA} | 40.1 | 37.15 ^{efB} | 13.2 | 13.90 ^{aA} | 18.3 | 5.71 ^{dA} | 22.6 |
| | | 7 days ⁽⁶⁾ | 33.14 ^{cA} | 4.2 | 13.96 ^{aA} | 18.9 | 6.06 ^{deA} | 16.1 | 34.42 ^{cdB} | 5.2 | 13.74 ^{aA} | 5.3 | 6.13 ^{deA} | 11.2 |
| | | 14 days ⁽⁶⁾ | 33.13 ^{cA} | 10.7 | 13.86 ^{aA} | 18.1 | 6.00 ^{cdA} | 29.8 | 34.24 ^{cdB} | 11.6 | 14.06 ^{aA} | 13.0 | 6.89 ^{eB} | 29.6 |

(n) = repetitions number; CV% = Coefficient of variation; Mean \pm standard deviation; Different lowercase letters in columns and capital letters in rows, of each variable, indicate significant differences ($p < 0.01$); **Biceps femoris*.

to 62% in the amount of blood drained resulting in an increase in the meat quality and acceptance due to a less pronounced red color (lower a^*).

The meat maturation also caused changes ($p < 0.01$) in the color parameters (L^* , a^* , and b^*). The values of this treatment were, respectively, 35.72, 14.05, and 6.87 for the samples without aging; 33.27, 13.68, and 6.59 for the samples aged for 7 days; and 32.53, 13.53, and 5.83 for the samples aged for 14 days. It was observed that the samples aged for both 7 and 14 days were darker (lower L^*) than the non-aged samples. There was no change in the red intensity (a^*); however, the aged samples showed higher yellow color intensity (b^*) than the non-aged samples exhibiting a brownish red color, typical of aged meat.

The average values of color parameters observed in this study for the AT effects are within the ranges cited by Sañudo et al. (2000) for sheep, 30.03-49.47 for L^* , 8.24-23.53 for a^* , and 3.38-11.10 for b^* .

Among all treatments, the injection of 0.2 M CaCl_2 was the one that affected the meat characteristics the most including changes in the color parameters. The average values observed for this treatment were 32.71-34.96 for L^* , 13.80-13.71 for a^* and 6.07-6.80 for b^* , for the treatments without and with CaCl_2 respectively.

The injection of CaCl_2 increased ($p < 0.01$) the lightness (L^*) and the yellow intensity (b^*) resulting in a lighter yellowish red colored meat.

Zeola et al. (2005), working with ewes, did not find color differences for the CaCl_2 treated meat obtaining values of 38.35, 37.45, and 38.17 for L^* ; 16.80, 16.45, and 15.94 for a^* , and 4.90, 3.72, and 4.94 for b^* , respectively, for untreated samples and for samples injected with 0.2 M or 0.3 M of CaCl_2 solution. Later, Zeola et al. (2007), working with lambs, did not find effect of CaCl_2 treatment either obtaining values of 40.51 and 40.96 for L^* , 15.83-16.21 for a^* , and 3.91 and 4.89 for b^* , respectively, for the samples untreated and treated meat samples.

3.4 Sensory evaluation

The values of the statistical analysis of the data of the sensory evaluation of tenderness (duo-trio test) of the *Biceps femoris* muscle samples of ewes are presented in the Table 4.

The comparison between the samples treated or not with 0.2 M CaCl_2 solution considered only the tenderness attribute

Table 4. Sensory evaluation of tenderness (Duo-trio test) of *Biceps femoris* muscle of Santa Inês ewes submitted to different aging periods with or without treatment with 0.2 M solution of calcium chloride.

| Treatments | Total of answers | Correct answers | Incorrect answers |
|-------------------|------------------|-----------------|-------------------|
| Non-aged meat | 70 | 43 (61.4%)* | 27 (38.6%) |
| 7 days aged meat | 55 | 36 (65.5%)** | 19 (34.5%) |
| 14 days aged meat | 52 | 39 (75.0%)*** | 13 (25.0%) |

Significant differences according to the table of minimum number of correct selections for a significant difference (ROESSLER et al., 1978). *($p < 0.05$), **($p < 0.02$), ***($p < 0.01$).

and was made for each meat aging period (0, 7, and 14 days). The number of correct answers indicates the accuracy in identifying the sample that was similar to the reference showing the differences between the samples compared and therefore between the treatments.

According to the table of minimum number of corrected selections for significant differences for the Duo/Trio test (ROESSLER et al., 1978), there were differences ($p < 0.05$) between untreated and treated meat samples with CaCl_2 . In this analysis, 43 (61.4%) of the responses identified correctly the reference sample with 36 correct answers (83.7%) indicating the samples treated with CaCl_2 as the most tender.

For the meat aged for 7 days, differences ($p < 0.02$) were observed due the treatment with CaCl_2 ; 36 responses (65.5%) correctly identified the reference sample, from which 31 (86.1%) indicated the samples treated with CaCl_2 as the most tender.

Similarly, differences were observed between the samples aged for 14 days ($p < 0.001$); 39 responses (75%) correctly identified the reference sample, from which 37 responses (94.9%) indicated the samples treated with CaCl_2 as the most tender.

Data from sensory analysis confirmed the tenderness results found in the evaluation of SF, which indicated the samples treated with CaCl_2 as softer than the untreated samples, independently of the aging time.

4 Conclusions

The recovery of the body condition improves meat tenderness in approximately 8%; it does not affect cooking loss; changes the meat color increasing brightness and reducing the intensity of the yellow. Electrical stimulation increases the tenderness by about 24%; it does not affect the cooking loss and does not change any of the color parameters. Meat aging increases tenderness by about 18 to 26% depending on the aging time (7 or 14 days) and its effects are magnified by carcass electrical stimulation; it increases cooking loss and changes the color parameters making the meat darker and accentuating the yellowness, resulting in a brownish red colored meat. The injection of 0.2 M CaCl_2 proved the most effective process in meat tenderization with a reduction of approximately 35% in shear force; it results in higher cooking loss and changes the color of the meat making it lighter and accentuating the yellowness.

It can be concluded that all the procedures evaluated were effective in improving the quality of the meat of old ewes discarded due to age showing a greater effect when used in a concomitantly. These processes may be adopted as a routine by the sheep meat industry.

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