



## Toughness in Santa Inês lamb meat has negative impact on consumer evaluation

*Dureza na carne de cordeiros Santa Inês tem impacto negativo na avaliação do consumidor*

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## SUMMARY

Meat tenderness is a major attribute for consumers worldwide. However, few studies investigate the importance of lamb meat tenderness for Brazilian consumers. This study assessed consumers' evaluation of lamb meat with high shear forces. Eight lambs were slaughtered at  $32.5 \pm 2.5$  kg of live weight and 5 to 6 months of age. The *Longissimus dorsi* muscle from both half carcasses was randomly assigned to four different *postmortem* processes: Tough Meat (TM), obtained by cold shortening, Fresh Meat (FM), Aging for 3 (A3) and 7 (A7) days *postmortem*. The variables measured were the sarcomere length, shear force (WBSF) and myofibrillar fragmentation index. We also applied the sensory analysis using affective acceptance tests with hedonic scale of nine points to measure texture, juiciness and overall quality of the meat. The *postmortem* processing for TM resulted in shorter sarcomere and greater shear values ( $p < 0.05$ ) compared to all other samples, while FM, A3 and A7, did not differ between the samples. Myofibrillar fragmentation was greater for A7 compared to TM ( $p < 0.05$ ), while FM and A3 showed intermediate values that did not differ between the treatments. In the sensory analysis, TM samples received significantly lower scores ( $p < 0.01$ ) for all attributes compared to other treatments and the attributes were not different between the *post rigor* processes. Consumers identified and evaluated negatively the meat samples with high WBSF. However, further studies are needed to elucidate the impact of smaller differences in WBSF, at intermediate values, on consumers' evaluation.

**Key words:** Acceptance, Sarcomere length, Shear force, Tenderness

## RESUMO

A maciez da carne é um atributo importante para os consumidores do mundo todo. Porém, ainda faltam estudos sobre sua importância na área de carne de cordeiro para consumidores brasileiros. O objetivo

do estudo foi verificar a avaliação dos consumidores em relação à carne de cordeiro com força de cisalhamento elevada. Oito cordeiros foram abatidos com  $32,5 \pm 2,5$  kg de peso vivo e 5 a 6 meses de idade. O músculo *Longissimus dorsi* das meias carcaças foi distribuído aleatoriamente em quatro diferentes processamentos *postmortem*: Carne Endurecida (CE), obtido pelo encurtamento pelo frio, Carne Fresca (CF), maturada por 3 (M3) e 7 (M7) dias *postmortem*. As variáveis medidas foram comprimento do sarcômero, força de cisalhamento (FC), índice de fragmentação miofibrilar (IFM) e testes sensoriais de aceitação afetiva com escala hedônica de nove pontos para textura, suculência e qualidade global. O processamento *postmortem* para CE resultou em menor sarcômero e maiores valores de FC ( $p < 0,05$ ) em comparação com outras amostras, enquanto estas não diferiram entre si. O IFM foi maior para M7 em relação à CE ( $p < 0,05$ ), enquanto CF e M3 apresentaram valores intermediários que não diferiram. No teste sensorial, as amostras de CE receberam escores menores ( $p < 0,01$ ) para todos os atributos comparados aos demais tratamentos, que não diferiram entre si. Os consumidores avaliaram negativamente a carne que apresentou alta FC. Porém, estudos devem ser realizados para elucidar o impacto de diferenças menores, em faixas intermediárias de FC, na avaliação do consumidor.

**Palavras-chave:** Aceitação, Comprimento de sarcômero, força de cisalhamento, maciez

## INTRODUCTION

Sheep farming in Brazil is increasing, with a growth of 12% of heads between 2004 and 2012 (INSTITUTO FNP, 2014). The fast farming cycle, with the reproductive life starting at 10 months old and slaughter before 6 months old, has been an important characteristic to boost this growth. The breeding of Santa Inês has gained interest and is increasing, because this breed fits these



characteristics well and has high adaptability to several types of environment (FREIRE et al., 2010).

Despite the increasing herd, production is still not sufficient to supply the Brazilian market (FIRETTI et al., 2010; BRASIL, 2015). Moreover, production of lamb meat faces issues mainly because of low product standardization, shortage of continuous supply (FIRETTI et al., 2010), and high prices (FIRETTI et al., 2010; ANDRADE et al., 2016).

Among the organoleptic quality attribute s(color, texture, juiciness and flavor), texture is the most important sensory characteristic for preference and acceptance by consumers, as well as for their decision to purchase (KOOHMARAIE, 1994; STARKEY et al., 2015). Texture perceived by consumers can be measured through sensory methods and is related to shear force measurements (CULLER et al., 1978). Within sensorial analysis, there are affectionate methods, which demonstrate a product potential through the direct opinion of consumers about specific characteristics (MEILGAARD et al., 1999).

Tenderness is partially defined by the toughening phase that occurs during *rigor mortis*. Meat toughening is generated by the shortening of sarcomere associated to an increase on shear force and meat toughening may be reverted by aging (WHEELER & KOOHMARAIE, 1994; KOOHMARAIE et al., 1998). Cold shortening is very common in commercial conditions. Animal size associated to lack of fat covering results in fast decrease of the carcass temperature during the cooling (MONIN & SANTÉ-LHOUELLIER, 2014; OCKERMAN & BASU, 2014).

There are no specific data on the sensory perception of lamb tenderness

in Brazil, or on its influence on the consumer choice. Thus, this research investigated the consumer's perception and its impacts on sensory evaluation in meats by induction of sarcomere shortening and aging, at different tenderness ranges.

## MATERIAL AND METHODS

The project was approved by Ethics Research Committee of FZEA/USP (CAAE 44737515.6.0000.5422).

This study used 16 samples of the *Longissimus dorsi* muscle from half carcasses of eight lambs raised at sheep production sector at the Faculty of Animal Science and Food Engineering from the University of São Paulo (FZEA / USP). The lambs were from Santa Inês breed, not castrated and slaughtered at approximately 6 months old. They were raised in a semi-intensive management system in Coast-cross grass and supplemented with concentrate of 2% of live weight, offered once a day in a covered feeding trough. Water and mineral salts were offered *ad libitum*.

The 16 samples of LD were randomly distributed among four different types of *postmortem* processes; however, it was respected the same number of LD originated from right and left half carcass per treatment and ensuring that same animal would not have the same treatment assigned to both loins from its pair of half carcasses, to obtain different ranges of shear force (SF), as follow:

- Toughened meat (TM): a procedure was conducted to ensure sarcomere shortening between 20 and 40% of resting sarcomere length to obtain higher shear force. For this reason, the muscles were excised immediately after slaughter, packed in plastic bags and then placed into a cool box with water and ice at 0°C, where



they were kept for 2 hours. The muscles were vacuum packaged and frozen until the analysis, according to Rees et al. (2002).

- Fresh meat (FM): the muscles were excised from the carcasses, that were kept in a cold chamber at 2-4°C for 24 hours before deboning. The muscles were vacuum packaged and frozen until the analysis.
- Aging meat for 3 days (A3): the LD was removed from the carcasses, that were kept in a cold chamber at 2-4°C for 24 hours before deboning, and vacuum packaged, left to age at 1°C for 3 days in a controlled temperature refrigerator, and frozen until the analysis.
- Aging meat for 7 days (A7): the LD was removed from the carcasses, that were kept in a cold chamber at 2-4°C for 24 hours before deboning, and vacuum packaged, left to age at 1°C for 7 days in a controlled temperature refrigerator, and frozen until the analysis.

After completing the treatments, the following analyses were performed:

*The pH and temperature.* The pH was measured through a digital portable pH meter (model: DM-2, Digimed) and the temperature was measured with a digital spike thermometer (brand: Logen Scientific). Two measurements were made, one soon after slaughter and the other 24 hours *posts* slaughter, except for the TM.

*Thawing loss(TL).* In this analysis, 3 steaks from LD with 2.5 cm of thickness were used. The samples were removed from the package, dried to remove exudate water, and weighed frozen. Afterward, they were frozen in a freezer with controlled temperature at 2°C overnight. On the next day, the samples were dried and weighed again.

The TL was determined by the difference between weights before and after thawing (MISSIO et al., 2010).

*Cooking loss (CL).* In this analysis, 3 steaks from LD of 2.5 cm thickness were used. The samples were weighed and cooked in a preheated electric oven. At 36°C, the samples were turned over and kept in the oven until the internal temperature of 72°C (temperature was controlled by a digital thermometer). Afterward, the steaks were left to cool at room temperature and were weighed again. The CL was determined by the difference between the weight after and before cooking (FELÍCIO, 1999).

*Shear force (SF).* The procedure was performed according to the recommendations of the American Meat Science Association - AMSA (2010). The same samples used to CL were used to analyze the shear force. Five to eight cylinders of 1.25cm of diameter, cut following the direction parallel to the muscle fibers, were removed from the steaks. The SF was measured through Warner-Bratzler texturometer (G-R Manufacturing Co., Manhattan, KS, USA). The results are expressed in kgf.

*Myofibrillar fragmentation index (MFI).* The MFI was determined in accordance to procedures described by Culler et al. (1978), with the following adaptations: 1g of muscle sample was homogenized in 10 MFI buffer volume. The protein concentration was determined by the biuret method described by Gornall et al. (1949). The protein concentration was adjusted to ensure the same protein concentration of 5 mg.ml<sup>-1</sup>. The myofibrillar suspension was diluted and stirred, and absorbance was read immediately in the spectrophotometer (brand Unico, model 1205) at 540nm



wavelength. The index was calculated according to Culler et al. (1978).

*Sarcomere length* (SL). Five pieces (sub-samples) were cut transversely to the cross sectional area of LD from medial, dorsal-intermediary, intermediary, ventral-intermediary and lateral locations in the muscle surface. The fixation method for contrast microscope described by Cross et al. (1981) and Koolmees et al. (1986) was used in the analysis. Each sub-sample was placed in a small bottle with 5% glutaraldehyde for 4 hours, and subsequently this solution was exchanged by a 0.2M sucrose solution and left over night. Both solutions have 0.1M phosphate buffer (pH=7.2) as basis. The samples can be kept in the sucrose solution up to 7 days. For slide preparation, each sub-sample was homogenized in Ultra-Turrax IKA (model T25 D), and a small part was placed on a slide and covered with a glass. In each slide, five different measurements were obtained and each measurement covered 10 to 20 sarcomeres of myofibrils linearly stretched. The Nikon Eclipse 80i contrast microscope was used with 100x magnifying lens. The Nikon Elements F program was used to measure the sarcomere in the photomicrographs.

*Chemical composition.* The samples were homogenized with a multiprocessor and chemical composition was determined in accordance to the ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS - AOAC (2005), for the contents of moisture (method 950.46), ashes (method 920.153), lipids (method 991.36) and total protein for AOAC (1995) (method 981.10). For sensorial analysis, the following preparations were made:

*Samples preparation.* After thawing in refrigerated environment (2°C), the samples were immersed in 10 % sodium chloride solution and kept in the refrigerator for 30 minutes (SIQUEIRA et al., 2002). Soon after, the samples were cut in steaks and cooked, as described in Cooking Loss. Immediately after cooking, the samples were chopped into cubes and kept in an oven at 50°C for at most 15 minutes.

*Sensory evaluation in individual booth.* The evaluations were conducted in Laboratory of Sensory Analysis at FZEA/USP, with the participation of 50 untrained consumer panelists. These consumers were selected randomly within students of USP/Pirassununga between 18 and 25 years old and 57.7 % of the participants were women.

*Free and Informed Consent Term* was provided by the consumer panelists. Each consumer received a 2-cm<sup>3</sup> meat sample from each treatment. Samples were presented in small and properly coded cups. The order of the treatments was randomized; therefore, consumers did not receive samples in the same sequence in consecutive panels. An acceptance test was conducted using the hedonic scale of nine points (1= Hated; 2= Very disliked; 3= Disliked moderately; 4= Slightly disliked; 5 = Not liked/not disliked; 6= Slightly liked; 7= Liked moderately; 8= Liked very much; 9= Loved), as described by Meilgaard et al. (1999). The following characteristics were evaluated: tenderness, juiciness and overall quality. The analysis for meat quality and percent composition used the analysis of variance (ANOVA) in the PROC MIXED, and means were tested by Tukey at 5% of significance. The sensory evaluation was processed using the non-parametric analysis, and the





statistic difference was conducted using the Kruskal-Wallis test (PROC MIXED) at 1% of significance. Acceptance of meat sensory attributes was classified using the binomial test (PROC GLIMMIX) in which the grades were divided into two classes, agreed by

the author as Satisfactory (from 6 to 9) and Unsatisfactory (from 1 to 5), and means were tested by Tukey at 1 % of significance. All data were analyzed using the statistical package SAS (SAS INSTITUTE INC., CARY, NC, USA).

## RESULTS AND DISCUSSION

Table 1 – Chemical composition values of Santa Inês lamb loin subjected to toughening by cold shortening or aging in refrigerated condition

Variables, %	N	Postmortem processing				Standard error	P Value
		TM	FM	A3	A7		
Moisture	16	71.90	73.54	74.19	73.84	0.99	0.41
Lipid	16	6.16	5.16	4.30	5.11	1.14	0.85
Protein	16	20.75	20.20	19.56	20.17	0.28	0.35
Ash	16	0.93	0.99	0.89	0.84	0.05	0.38

TM= toughened meat, pre-rigor deboning with cold shortening in water bath at 0°C for two hours; FM= fresh meat, *post rigor* deboning without aging; A3= *post rigor* deboning aging for 3 days; A7= *post rigor* deboning aging for 7 days.

The percent composition of the loin samples from the four *postmortem* processes did not differ ( $p>0.05$ ) (Table 1), with average values of 75 %, 19 %, 4 % and 1 % for moisture, protein, lipid and ash, respectively. There was no

impact of *postmortem* processing on the chemical composition, since the values corroborate with the literature (BONAGURIO et al., 2004; ZAPATA et al., 2011).

Table 2 -Physical traits associated to the organoleptic quality Santa Inês lamb loin subjected to toughening by cold shortening or aging in refrigerated condition

Variables	N	Postmortem processing				Standard error	P Value
		TM	FM	A3	A7		
pH 0h	16	6.69	6.72	6.57	6.93	0.15	0.42
pH 24h	12	---	5.61	5.69	5.60	0.04	0.18
SL (µm)	16	1.44 <sup>b</sup>	1.84 <sup>ab</sup>	1.89 <sup>a</sup>	1.85 <sup>a</sup>	0.10	0.02
SF (kgf)	16	7.25 <sup>a</sup>	3.33 <sup>b</sup>	3.11 <sup>b</sup>	2.37 <sup>b</sup>	0.44	0.01
MFI	16	76.18 <sup>b</sup>	97.86 <sup>ab</sup>	115.55 <sup>ab</sup>	130.51 <sup>a</sup>	11.41	<0.01
TL (%)	16	17.69 <sup>a</sup>	13.16 <sup>a</sup>	8.00 <sup>b</sup>	6.76 <sup>b</sup>	0.58	<0.01
CL (%)	16	20.81	25.35	20.83	21.38	2.64	0.58

Sarcomere Length (SL), Myofibrillar fragmentation index (MFI), Shear Force (SF), Thawing Loss (TL), Cooking Loss (CL).

TM= toughened meat, pre-rigor deboning with cold shortening in water bath at 0°C for two hours; FM= fresh meat, *post rigor* deboning without aging; A3= *post rigor* deboning aging for 3 days; A7= *post rigor* deboning aging for 7 days.

<sup>a,b</sup> Means with different superscripts within the same row indicate a significant difference ( $p<0.05$ ; Tukey test).



There was no significant difference between the pH values at 0h00 and average value of  $6.73 \pm 0.15$  was within expectation, near neutral values. The pH measured at 24h00 had no significant differences between processes and were within the normal range for lamb meat, which for *post rigor* meat, are between 5.4 and 5.8. The average values were  $5.63 \pm 0.04$  (Table 2). The pH 24h00 for TM was not measured.

Considering the conditions of pH and temperature, the TM samples had all the conditions to characterize sarcomere shortening, due to muscle cooling in water at 0°C and initial pH around 6.72 – conditions that favor high shear force values. These conditions are predisposing factors for cold shortening, which occurs in muscles when pH is greater than 6 and temperature is below 10°C (LOCKER & HAGYARD, 1963). For TM, the sarcomere length was 1.44  $\mu\text{m}$  (Table 2), showing a shortening of 35 % when compared to the resting sarcomere length of 2.2  $\mu\text{m}$  obtained for lambs (WHEELER & KOOHMARIE, 1999). This shortening level allowed lower meat tenderness, when comparing meat that remained on carcass for 24 h (*post rigor*) or aged meat (M3 and M7); however, samples that did not undergo shortening differ from each other (Table 2). The shortening between 20 and 40 % was responsible for meat tightening (MARSH & LEET, 1966). High shear force values were also obtained at 24h *postmortem* in lamb meat with an average sarcomere length of 1.69  $\mu\text{m}$  (WHEELER & KOOHMARAIE, 1994). The sarcomere shortening, which occurs during the *rigor mortis*, is responsible for tightening the muscles, causing the toughening of *Longis simus* muscle in lambs (KOOHMARAIE et al., 2002). After rigor, the sarcomere length did not change significantly in

samples processed after 24h *postmortem* (Table 2).

The change in the shear force resulting from aging was not observed and the only difference verified in tenderness was related to the induction of cold shortening for TM (Table 2). The lack of differences between aged meats was not expected, since the objective of this work was to create tenderness ranges by exposing samples to cold shortening or aging, once larger changes in shear forces occur between the 1<sup>st</sup> and 7<sup>th</sup> day of the aging process (KOOHMARAIE et al., 1991, 1995, STARKEY et al., 2015). However, the temperature of the carcasses after slaughter did not have an expected cooling rate, reaching 12 to 15°C at 24 hours *post mortem*, which probably allowed rapid tenderization of FM and the aged samples. Incubation temperatures of the muscle *Longissimus* between 15°C to 20°C during rigor onset (first 16 hours *post mortem*) minimized the toughening effects of the muscle and accelerated the *postmortem* glycolysis process, with increased Desmin, Titin and Troponin-T degradation and  $\mu$ -calpain autolysis, resulting in lower shear force at 1day *postmortem* compared to very low (5°C) or very high (> 30°C) temperatures (GEESINK et al., 2000). These protein degradation patterns are all indicators of enhanced proteolysis and positively related to tenderization rate (DELGADO et al., 2001).

In lambs, the lack of differences between A3 and A7 were observed before, due to the faster tenderization process (GEESINK et al., 2000). This system also confirms that tender meats right after rigor tend not to have tenderizing effects due to the aging time. Although, differences could exist because of the fragility of myofibrillar structure caused by the *postmortem* proteolysis (MILLER, 2014). Although



there were no differences in shear force, the MFI seems to show a gradual increase of myofibrils fragmentation within the aging process. This study showed an increase in MFI, with significant difference observed between TM and A7, while FM and A3 did not differ between the PS (Table 2). The results were similar to those observed for older crossbred lambs, except for the major changes reported in MFI between the 3<sup>rd</sup> and 7<sup>th</sup> day of aging (GONÇALVES, et al. 2004). On the other hand, the lack of changes in shear force even with a steady increase in MFI were observed in callipygian lambs (KOOHMARAIE et al., 1995).

The *postmortem* process resulted in greater thawing loss for TM and FM, compared to A3 and A7 (Table 2). The

CL did not show differences, probably due to excessive thawing losses in MT and FM. The greater loss observed is linked to the storage of these muscles. Both processes underwent sarcomere shortening during the *rigor mortis*, and consequently the intramyofibrillar water spilled to the extramyofibrillar and extracellular spaces. However, this water is eventually retained in the meat, without the possibility of exudation because of sample freezing. On the other hand, muscles that undergo a longer aging time (3 and 7 days after slaughter), due to water channels formed in the extracellular space during aging, have drip losses with less free water retained in the extracellular spaces (DEVINE et al., 2014).

Table 3 - Sensory attributes of Santa Inês lamb loin submitted to toughening by cold shortening or aging in refrigerated condition

Variables	N	Postmortem processing				P Value
		TM	FM	A3	A7	
Texture	50	5.47 <sup>b</sup>	7.43 <sup>a</sup>	7.58 <sup>a</sup>	7.66 <sup>a</sup>	<0.01
Juiciness	50	6.45 <sup>b</sup>	7.75 <sup>a</sup>	7.57 <sup>a</sup>	7.57 <sup>a</sup>	<0.01
Overall Quality	50	5.92 <sup>b</sup>	7.37 <sup>a</sup>	7.53 <sup>a</sup>	7.54 <sup>a</sup>	<0.01

Grade scale: 1= Hated; 2= Very disliked; 3= Moderate disliked; 4= Slightly disliked; 5= Not liked/not disliked; 6= Slightly liked; 7= Moderate liked; 8= Very liked; 9= Loved.

TM= toughened meat, pre-rigor deboning with cold shortening in water bath at 0°C for two hours; FM= fresh meat, *post rigor* deboning without aging; A3= *post rigor* deboning aging for 3 days; A7= *post rigor* deboning aging for 7 days.

<sup>a,b</sup> Means with different superscripts within the same row indicate a significant difference ( $p < 0.01$ ; Kruskal-Wallis test).

The scores attributed to TM, which had SF of 7.2 kgf, were low compared to other processes, showing that SF has great impact on the sensory evaluation of consumers.

Samples classified as tenderer (SF below 3.40 kgf) received high scores in the sensory evaluation, except for TM. Meat of crossbred lamb (female and castrated) was qualified by consumers as tenderer, with values between 3.2 and 3.5 kgf, when compared to uncastrated lambs, which had SF of 4.1 kgf

(GONÇALVES et al., 2004), close to the threshold value of tender meat for consumers (<4.1 kgf) (MILLER et al., 2001; DELGADO et al., 2006). Gonçalves et al. (2004) used older lambs (15 months old with two permanent teeth) and, for this reason, other attributes, such as flavor and odor, probably influenced the low acceptance of uncastrated males. Different from the results of this research, which used young uncastrated lambs (6 months old).





Table 4 - Acceptance of the sensory attributes of Santa Inês lamb loin submitted to toughening by cold shortening or aging in refrigerated condition, using the binomial test<sup>1</sup>

Variables	N	Postmortem processing				P Value
		TM	FM	A3	A7	
Texture (%)	50	52±8 <sup>b</sup>	93±3 <sup>a</sup>	95±2 <sup>a</sup>	95±2 <sup>a</sup>	<0.01
Juiciness (%)	50	76±6 <sup>b</sup>	96±2 <sup>a</sup>	94±3 <sup>a</sup>	88±4 <sup>ab</sup>	<0.01
Overall Quality (%)	50	56±8 <sup>b</sup>	94±3 <sup>a</sup>	96±2 <sup>a</sup>	86±5 <sup>a</sup>	<0.01

<sup>1</sup> Satisfactory= 6 to 9 grades – equivalent to 100%; Unsatisfactory= 1 to 5 grades – equivalent to 0%.

TM= toughened meat, pre-rigor deboning with cold shortening in water bath at 0°C for two hours; FM= fresh meat, *post rigor* deboning without aging; A3= *post rigor* deboning aging for 3 days; A7= *post rigor* deboning aging for 7 days.

<sup>a,b</sup> Means with different superscripts within the same row indicate a significant difference (p<0.01, Tukey test).

In the acceptance analysis, TM obtained the lowest rates, resulting in a uniform distribution of scores in the lower range. The lowest preference for TM could be related to increase in shear force. Texture perception is highly affected by shear force for consumers of lamb meat. Samples with SF values lower than 2.7 kg were rated as high quality for most Australian consumers, while changing this threshold of SF to values lower than 4.9 kg, consumer acceptance decreased (HOPKINS et al., 2006).

Although FM and A3 had no differences when compared to A7, some comments were made in the evaluation for A7 samples, such as “the score was not higher, because this meat was too tender”, “this meat was too viscous”, or “it disintegrated too easy in the mouth”. These samples presented greater MFI (Table 2). These observations may indicate that exaggerated fragmentation of the myofibrillar structure in lamb meat may have detrimental influence on texture perception of some consumers. This may be explained by the high correlation (r=0.75) between MFI and the texture (CULLER et al., 1978).

Evaluating juiciness shows that TM is still the less accepted meat, even with better scores than for texture. Although there were no changes in moisture

between the processes (Table 1), TM received comments as “this meat is too dry”, which could probably happen since consumers tend to confuse juiciness with texture, associating tough meat to dry meat (MILLER, 2014).

In addition, A7 was more penalized regarding juiciness and were not different from TM. This reinforces the fact that MFI could influence acceptance, once juiciness is the moisture sensation in the first chewing, and it would not be clearly evaluated if the meat ‘disintegrates’ easily in the mouth.

The analysis of Overall Quality (Table 4) allows identifying the influence of juiciness and texture and the effects of other attributes not covered in this research, such as flavor, which also influence customers’ preference. This observation based on comments related to odor and taste that were not part of the attributes evaluated.

In the overall quality assessment, TM also received the lowest score, reflecting the results of texture and juiciness. Another element that may contribute to lower evaluations in the Overall Quality is odor, which presented comments as “strong odor” and “unpleasant odor”. On the other hand, A7 was not penalized in the



overall quality assessment when compared with either FM or A3, even though it had an unsatisfactory evaluation for juiciness, considering the distribution of scores. Therefore, even though lamb meat with very high MFI and low SF may be penalized, this was not enough to result in lower perception of overall quality. However, meat with low MFI and a high SF was consistently penalized and had a large number of unsatisfactory scores. The data suggests that texture plays a major role in the evaluation of the untrained consumers. Furthermore, since FM and A3 received the best scores in all attributes evaluated, those samples may be considered as standards for lamb meat quality.

## CONCLUSION

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Meat toughness caused by cold shortening has a negative impact on not only meat texture, but also on juiciness and overall quality evaluation by consumers.

The prolonged period of aging and greater myofibrillar fragmentation associated with it compromise evaluation of juiciness.

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