

Comparison of meat quality characteristics of dry aged lamb loins and optimization of dry aging process

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Abstract

The purpose of the present study was to investigate the physicochemical characteristics, meat quality, oxidative stability and sensory properties of lamb meat during 0, 7 and 14 day of the dry aging process. The *M. longissimus lumborum* (LL) and *M. longissimus thoracis* (LT) muscles from male Akkaraman lambs were used. The pH values of the LT and LL cuts were not changed during the aging periods. The LT cuts had significantly higher weight loss, *a** and *b** values, and lower shear force compared to the LL cuts. However, dry aging led to greater decreases in shear force in the LL cuts on 7th day of aging. The total mesophilic aerobic counts, total psychrophilic counts, *Enterobacteriaceae* counts, lactic acid bacteria, and yeast-mold counts were increased during the aging process. The sensory panel scoring showed a significant difference in the LL cuts and no significant difference in the LT cuts compared to the control group. There were significant changes in sensory panel scores for the LL cuts, whereas there were no significant changes for the LT cuts according to the non-aged samples. In conclusion, dry aging improved the quality of both cuts, however, the LL muscle of lamb was more suitable for dry aging. Moreover, 7 days were sufficient to produce the desired sensory properties in the lamb loins. Increasing the aging time from 7 to 14 days did not appreciably affect the sensory attributes or tenderness.

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Introduction

Over the last decade, sheep and lamb meat production has been increased and is becoming a national agribusiness because of social and economic demand in Türkiye.¹ There are approximately 35 million sheep in Türkiye and sheep meat production is the first target of sheep breeding.² Akkaraman breed is one of the local breeds and the majority of the sheep population (45.80%) in Türkiye due to its high-quality meat.³

Today's consumers prefer quality products for meat consumption. Dry aging method enhances the taste and tenderness of the meat or its parts at refrigerated temperatures provide quality meats for consumers, therefore, consumption and production of aged meat is increasing day by day.^{4,5} The process involves keeping the meat at 1.00 - 3.00 °C and 70.00 - 85.00% humidity approximately 21 - 28 days. In this process, unique flavor

and tenderness occur due to enzymatic and biochemical changes in the meat.⁶ The breakdown of proteins and fats produces intense flavor and this positively affects the consumers' preferences.

Meat processing is an important strategy for marketing and the application of dry aging to lamb meat is a good way to increase the marketing value of these meats. Furthermore, recent studies have revealed the possibility of developing sheep products.⁷⁻¹¹ Although several studies have been conducted on the production of lamb meat products, few studies have only focused on the tenderness and flavor of lamb meat.^{12,13} Moreover, there has been limited research on determining the effect of dry aging on the quality attributes of lamb meat.¹³ Therefore, the objective of this study was to investigate the effect of dry aging on the meat quality characteristics of *M. longissimus thoracis* and *M. longissimus lumborum* muscles from Akkaraman lambs.

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Materials and Methods

Sample preparation. A total number of 30 Akkaraman lambs (11-month-old) were used for this study. The study was approved by the Ethics Committee of the Faculty of Veterinary Medicine, University of Selcuk Konya, Turkiye (Report No: 2015/18). All animals were slaughtered humanely and dressed according to standard procedures of the commercial slaughtering plant. The average carcass weight was 45.00 kg. At 24 hr postmortem, *M. longissimus thoracis* (LT) and *M. longissimus lumborum* (LL) were cut from the 6th and 12th ribs, respectively, from both sides of each carcass and subcutaneous fat was not removed. LT and LL muscle were individually cut into pieces (each 700 ± 15.00 g, bone-in) for experiments with around $12.00 \times 8.00 \times 5.00$ cm dimension of the cut at different dry aging periods (0, 7 and 14 day). For dry aging process, totally 120 samples were stored on stainless steel gratings at 1.00 °C, 85.00% relative humidity, and 0.20 - 0.50 m sec⁻¹ airflow in a meat plant chiller (Teknik Buz, İstanbul, Turkiye). The temperature, humidity and air flow were monitored using a data logger (174H; Testo AG, Lenzkirch, Germany). The samples were turned over and rotated every day to minimize the effects of position. For the sensory analysis, sliced meat samples (2.00 cm thick) were taken from each sample and stored at - 20.00 °C in a vacuum pack.

Physicochemical analyses. The pH was measured on the cuts directly with a pH meter probe (205; Testo AG). Calibration was performed at pH 7.01 and 4.01 with standard buffers of the pH meter stored at room temperature. The water activity (a_w) value was measured using a portable hygrometer (Novasina AG, Lachen, Switzerland). It was calibrated with several saturated solutions [33.00% ($a_w = 0.332$), 58.00% ($a_w = 0.586$) and 84.00% ($a_w = 0.845$)] with known a_w values. The moisture content was measured using a moisture analyzer (MX-500; A&D Company Tokyo, Japan) calibrated using a special mass (AX-MX-41; A&D Company) and a temperature calibrator (AX-MX-43; A&D Company). The total weight loss during dry aging process was calculated as gram (g).

Instrumental color analyses. The surface color was determined by a CR-400 Chroma Meter (Konica Minolta, Tokyo, Japan) three times with an 8-mm diameter measuring aperture, a D65 illuminant and 2.00 °C standard observers. The standards for lightness (L^*), redness (a^*) and yellowness (b^*) were calibrated using a standard white tile ($L^* = 97.65$, $a^* = - 0.10$, $b^* = - 0.14$) before measurement. Samples were allowed to bloom for 30-min at 2.00 °C before initial color measuring.¹⁴

Thiobarbituric acid reactive substance (TBARS). Thiobarbituric acid reactive substances were determined according to the method described by Tarladgis *et al.*^{15,16}

The absorbance of the samples was measured with a spectrophotometer (UV-1601 Visible; Shimadzu, Tokyo, Japan) against the blank (5.00 mL of distilled water) at 530 nm. The TBARS values were calculated as mg malondialdehyde (MA) per kg (mg MA kg⁻¹).

Warner - Bratzler shear force (WBSF). Warner-Bratzler Shear Force values were measured using a Texture Analyzer (TA.HDPlus; Stable Microsystems Godalming, Surrey, UK) with WBS (TA-7) probe.¹⁷ The steaks (2.00-cm-thick) were cooked on an electric grill until a core temperature of 70.00 °C was obtained. The internal temperature was monitored with thermocouples (175T2 Data logger; Testo AG). After cooking period, the steaks were overwrapped in polyvinyl chloride film and stored at 4.00 °C for 24 hr. From each sample, 10 cylindrical cores (1.27 cm diameter) were obtained from parallel to the muscle fibers using a mechanical coring device. The cores were cut with shear blade at a crosshead speed of 200 mm per min. WBSF values were recorded as newton (N).¹⁸

Sensory analyses. Sensory analyses of the meat samples were conducted according to the methods described by the American Meat Science Association.¹⁸ Frozen samples were thawed for 24 hr at 4.00 °C. Each sample was cut into 60.00 × 20.00 × 6.00 mm sizes and roasted on an electric grill until the core temperature was reached 72.00 °C.¹⁸ After cooking procedure, each sample was cut into 2.00 × 2.00 cm squares (with no edges, visible fat, or tendons), randomly codified, wrapped in aluminum foil and kept warm until the examination within 15 min. The sensory attributes were evaluated by an untrained consumer panel (30 sensory panelists) using the LT and LL cuts (7 and 14 day aged) compared to non-aged cuts (control, 0 day). A total number of thirty sensory sessions were conducted with the same panelists. Each panelist evaluated five samples at each session. The sensory analyses evaluated four traits: Juiciness, tenderness, flavor, and overall like of the meat using a 10-point hedonic scale (1 = extremely disliked to 10 = extremely liked).

Microbiological analyses. The total mesophilic aerobic count (TMAC), total psychrophilic count (TPC), *Enterobacteriaceae*, lactic acid bacteria (LAB), and yeast-mold were analyzed according to BAM-2001, ISO 17410-2001, ISO 21528-2-2017, ISO 15214-1998, and ISO 21527-1-2008 guidelines, respectively.¹⁹⁻²³ Before weighing and trimming, 10.00 g of the samples representing the whole meat, were transferred to sterile stomacher bags and mixed in a lab stomacher for 2 min with the addition of 90.00 mL Maximal Recovery Diluent (Merck, Darmstadt, Germany). Appropriate serial dilutions were prepared using 9.00 mL maximal recovery diluent. Pour plate method (added 1000 µL sample) were used with plate count agar (Merck), violet red bile dextrose agar (Merck), dichloran rose Bengal chloramphenicol agar (Merck), for TMAC, TPC, *Enterobacteriaceae*, and yeast-mold analysis,

respectively. Spread plate method (added 100 µL sample) were used with DeMan–Rogosa–Sharpe agar (Merck) for LAB analysis. Appropriate dilutions were plated in duplicates and the colonies were enumerated after suitable incubation temperature and time for each bacterium. The number of the colonies were expressed as log (CFU g⁻¹).

Statistical analyses. All measurements were performed in triplicate. The data were evaluated by analysis of variance using SPSS for Windows Software (version 21.0; IBM Corp., Armonk, USA). Sensory panel data were collected, averaged across panelist and analyzed as a split-plot design. The statistical differences between the means were compared using Duncan's Post-Hoc Test, and the statistical significance of the mean values was set at $p < 0.05$. The results are reported as means \pm standard error of the means.

Results

Physicochemical analyses. Physicochemical analyses results are given at Table 1. The initial average pH of the LT and LL samples at 24 hr postmortem was 5.67 and 5.56, respectively (Table 1). The initial pH of the LT samples was slightly higher than that of the LL samples ($p < 0.05$). The aging period had no impact on the pH values of LT and LL cuts ($p > 0.05$). During dry aging process, weight loss was increased in both LT and LL cuts. After 7 days of aging, LT and LL samples showed weight loss ranging from 700 g to 609 g and 634 g, respectively (Table 1). After 14 days of dry aging, LT and LL samples displayed weight loss ranging from 700 g to 570 g and 607 g, respectively (Fig. 1). The LT cuts had significant differences compared to the LL and 0-day samples during 7 days aging ($p < 0.05$). The changes in weight loss between the 7 and 14 days of aging, LT samples had significant differences ($p < 0.05$). While 7 days aging caused significant differences in weight loss in the LL cuts ($p < 0.05$), the changes in weight loss results between the 7- and 14-days aging were no significant ($p > 0.05$).

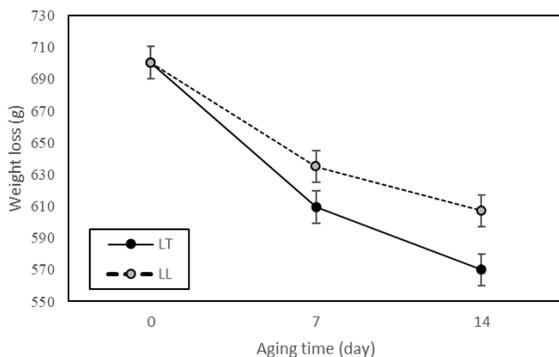


Fig. 1. Weight loss of dry aged *Longissimus thoracis* (LT) and *Longissimus Lumborum* (LL) muscles during dry aging periods. The error bars represent the standard error ($p > 0.05$).

Thiobarbituric acid reactive substance (TBARS).

During dry aging process, aging time increased the production of TBARS in both the LT and LL samples (0.23 - 0.69 mg MA per kg and 0.21 - 0.74 mg MA per kg, respectively). Besides, there were no significant differences in TBARS results among the LT and LL at 7 and 14 days ($p > 0.05$). The changes in moisture and the a_w values tended to be decreased during the aging period but differences were not significant in either muscle ($p > 0.05$).

Warner-Bratzler shear force. The statistical outputs for WBSF can be seen in Table 1. In initial day of the aging (0-day), there were differences in the WBSF values among the cuts ($p < 0.01$). The results of the LT and LL samples aged for 7 days were different from the values before aging (0-day, $p < 0.05$), however, they were not different from samples aged for 14 days ($p > 0.05$). LT and LL cuts had significant differences on 14 days aging ($p < 0.001$). The aging treatments affected the WBSF values of the LL and LT samples ($p < 0.05$).

Instrumental color analyses. The color changes in the samples during the aging period are given in Table 2. According to our results, the aging method had significant effects on the a^* and b^* values ($p < 0.001$), but not on the L^* values of LT cuts ($p > 0.05$). At the beginning of the aging process, the LL cuts had higher (36.97 ± 0.87) L^* values than the LT cuts (34.16 ± 0.74). However, on 7 days aging, there were significant differences in L^* values between the LT and LL cuts ($p < 0.05$), and by 14 days this difference had mostly disappeared. The changes in a^* and b^* values of the LT samples during the aging period were statistically significant ($p < 0.001$) and the results showed an increase from 7 days of aging. However, dry aging process had no impact on L^* , a^* and b^* values of LL cuts.

Sensory analysis. The statistical outputs for sensory analysis can be seen in Table 2. The sensory panel detected significant differences in flavor, juiciness, tenderness and overall acceptability of the LL samples ($p < 0.05$). After 7 days of dry aging process of the LL cuts significant differences were found in all sensory traits ($p < 0.05$). The sensory analyses showed higher scores for flavor, juiciness, tenderness and overall like of the LL cuts on the 7 days of aging (9.00 ± 0.50 , 8.11 ± 0.40 , 8.62 ± 0.40 and 8.82 ± 0.40 , respectively). However, increasing the aging time did not appreciably affect the sensory attributes of LT cuts ($p > 0.05$).

Microbiological analyses. The results of the microbiological properties of the samples are shown in Figures 2 and 3. At the end of the dry aging process, TMAC, TPC, LAB, *Enterobacteriaceae* and yeast-mold counts were similar ($p > 0.05$) for both LT and LL cuts. Increase in TPC, LAB and yeast-mold counts of the LT and LL samples were insignificant during the aging process ($p > 0.05$). *Enterobacteriaceae* counts were lower than the other microorganism groups and were not different ($p > 0.05$) among the cuts.

Table 1. Physicochemical analyses results.

Traits	Muscle	Day 0	Day 7	Day 14	p-value
pH	LT	5.77 ± 0.00 ^a	5.86 ± 0.07	5.97 ± 0.05	***
	LL	5.56 ± 0.01 ^{zb}	5.70 ± 0.01 ^y	5.91 ± 0.04 ^x	
	<i>p</i>	***			
TBARS (mg MA kg ⁻¹)	LT	0.23 ± 0.02 ^y	0.55 ± 0.10 ^{xy}	0.69 ± 0.17 ^x	*
	LL	0.21 ± 0.06 ^y	0.62 ± 0.14 ^x	0.74 ± 0.16 ^x	*
	<i>p</i>				
a _w	LT	0.96 ± 0.00	0.97 ± 0.00	0.97 ± 0.00	
	LL	0.97 ± 0.00	0.97 ± 0.00	0.97 ± 0.00	
	<i>p</i>				
Moisture (%)	LT	73.15 ± 0.80	71.47 ± 1.37	70.06 ± 1.48	
	LL	73.81 ± 0.58 ^x	72.25 ± 0.49 ^y	72.03 ± 0.39 ^y	
	<i>p</i>				
Weight Loss (g)	LT	700 ± 15.00 ^x	609 ± 9.70 ^y	570 ± 9.50 ^z	*
	LL	700 ± 15.00 ^x	634 ± 9.80 ^y	607 ± 9.40 ^y	*
	<i>p</i>				
WBSF (N)	LT	22.96 ± 1.66 ^{xb}	18.95 ± 1.39 ^y	17.36 ± 0.74 ^{yb}	*
	LL	33.11 ± 1.72 ^{xa}	23.73 ± 1.97 ^y	22.45 ± 0.75 ^{ya}	***
	<i>p</i>	**		***	

LT: *Longissimus thoracis*; LL: *Longissimus lumborum*; TBARS: Thiobarbituric acid reactive substances; WBSF: Warner-Bratzler shear force.

^{ab} Values within a column with different letters are significantly different ($p < 0.05$); ^{xyz} Values within a row with different letters are significantly different ($p < 0.05$); * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$.

Table 2. Color and sensory evaluation results.

Traits	Muscle	Day 0	Day 7	Day 14	p-value
Lightness	LT	36.97 ± 0.87 ^a	37.95 ± 1.15 ^a	36.14 ± 0.93	
	LL	34.16 ± 0.74 ^b	34.74 ± 0.69 ^b	35.26 ± 0.75	
	<i>p</i>	*	*		
Redness	LT	12.36 ± 0.57 ^{ya}	14.05 ± 0.33 ^x	14.42 ± 0.47 ^x	**
	LL	12.41 ± 0.56 ^b	11.90 ± 0.75	11.07 ± 0.79	
	<i>p</i>	*			
Yellowness	LT	7.23 ± 0.30 ^y	8.44 ± 0.52 ^x	9.53 ± 0.33 ^x	**
	LL	7.68 ± 0.25	6.49 ± 0.27	6.80 ± 0.25	
	<i>p</i>				
Flavor	LT	7.33 ± 0.40	8.33 ± 0.30	8.22 ± 0.70	
	LL	7.00 ± 0.50 ^y	9.00 ± 0.50 ^x	9.22 ± 0.60 ^x	
	<i>p</i>				
Juiciness	LT	7.00 ± 0.30	8.44 ± 0.50	7.56 ± 0.60	
	LL	6.22 ± 0.40 ^y	8.11 ± 0.40 ^x	7.89 ± 0.60 ^x	
	<i>p</i>				
Tenderness	LT	7.56 ± 0.40	8.22 ± 0.50	8.22 ± 0.50	
	LL	6.67 ± 0.70 ^y	8.62 ± 0.40 ^x	8.37 ± 0.30 ^{xy}	
	<i>p</i>				
Overall like	LT	7.33 ± 0.40	8.33 ± 0.40	8.11 ± 0.60	
	LL	7.00 ± 0.60 ^y	8.82 ± 0.40 ^x	8.70 ± 0.50 ^x	
	<i>p</i>				

LT: *M. Longissimus thoracis*, LL: *M. Longissimus lumborum*.

^{ab} Values within a column with different letters are significantly different ($p < 0.05$); ^{xy} Values within a row with different letters are significantly different ($p < 0.05$); * $p < 0.05$; and ** $p < 0.001$.

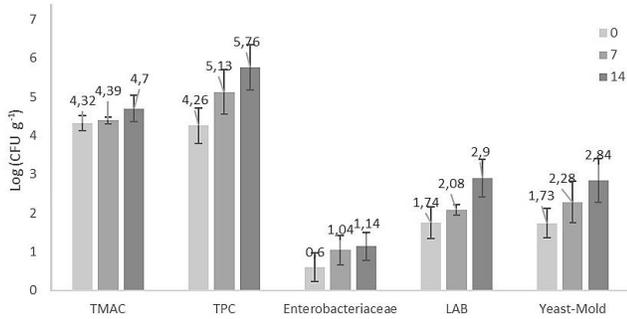


Fig. 2. Microbiological results of the LT samples (log CFU g⁻¹). LT: *M. Longissimus thoracis*; TMAC: Total mesophilic aerobic counts; TPC: Total psychrophilic counts; LAB: Lactic acid bacteria. The error bars represent the standard error ($p > 0.05$).

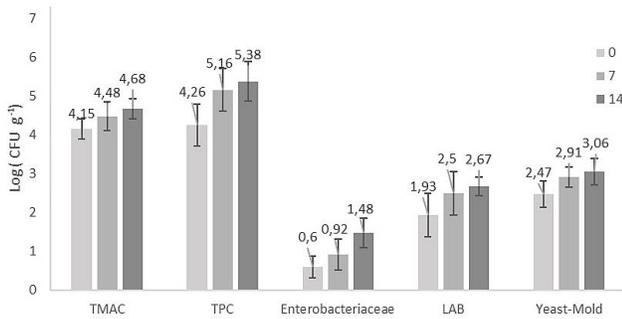


Fig. 3. Microbiological results of the LL samples (log CFU g⁻¹). LL: *M. Longissimus lumborum*; TMAC: Total mesophilic aerobic counts; TPC: Total psychrophilic counts; LAB: Lactic acid bacteria. The error bars represent the standard error ($p > 0.05$).

Discussion

The pH is usually considered as a major determinant of meat quality.²⁴ The meat with high quality has a pH in the range 5.40 - 5.60 and the meat quality decreases at pH values above 6.00.²⁵ In our study, the aging period had no impact on the pH values of LT and LL cuts. Similarly, previous studies showed that aging process had little or no effect on beef pH, regardless of aging period.²⁶⁻³¹ According to final pH values, the LL and LT cuts were still acceptable on 14th day (all cuts were below pH 6.00 on day 14).²⁵ It has reported that the changes in pH and lipid oxidation during the storage had a major effect on the quality, palatability and texture of the meat.³² In this study, the TBARS results indicated that all samples could be consumed (< 1.00 mg MA per kg) even on day 14.^{33,34}

During dry aging process, weight loss was increased in both the LT and LL cuts. LL cuts showed significantly higher yields than LT on 7 and 14 days of aging. The amount of subcutaneous fat on the upper surface of the LL samples could inhibit water evaporation of meats. Besides, the increased weight loss of the LT cuts affects the economic value of the product. The present findings were consistent with the results of Smith *et al.* who mentioned the high weight loss and low saleable yields would lead to a higher price for dry aged products.³⁵

Our findings showed that the postmortem aging enhanced tenderness in both lamb loins and these were clearly consistent with Pinkas *et al.* and Jeremiah *et al.*^{36,12} Besides, the WBSF values on day 14 were different between the cuts and indicated that the LT samples were more tender than the LL samples ($p < 0.001$). According to our results, the dry aging treatments led to more decrease in WBSF values of the LL cuts than LT cuts (from 33.11 ± 1.72 to 22.45 ± 0.75 at 14 days). This difference was probably because of the types of fibrils and the amount of connective tissue in the muscles as well as differences in the shear force on the initial day of aging.³⁷⁻³⁹ Furthermore, the WBSF results of the LT and LL cuts were not changed after 7 days of aging. These results indicated that the aging period could be limited by 7 days to produce tender and high yielded lamb meat. Also, Feiner demonstrated that lamb meat required around 7-10 days to become tender.⁴⁰

Dry aging of the LT cuts showed a dark red color with increased a^* and b^* values due to the conversion of oxymyoglobin to metmyoglobin through heme pigment oxidation.⁴¹⁻⁴³ Also, Kim and Hunt reported that meat with lower amounts of water absorbed more light and the surface became darker, resulting in higher a^* values.⁴⁴ Besides, Kim *et al.* reported that color stability could be changed by several factors including the oxygen consumption rates and the metmyoglobin reductase activities in the different muscle types.²⁶

In this study, dry aging improved the sensory traits of the LL samples. The sensory analyses showed higher scores for tenderness of the LL cuts, which was in accordance with the WBSF results. The sensory analyses showed higher scores for tenderness of the LL cuts on 7 days of aging (8.62 ± 0.40). However, increasing the aging time from 7 to 14 days did not appreciably affect the sensory attributes or tenderness. In general, our findings agreed with the results of Warren and Kastner, and Campbell *et al.* who reported that dry aging improved sensory evaluation scores of tenderness and flavor of beef loins.^{6,45}

The EU Regulation No. 2073/2005 states that 5.00 log CFU g⁻¹ is an acceptable limit for beef and sheep carcasses for TMAC.⁴⁶ According to our results, the TMAC and *Enterobacteriaceae* counts of the LT and LL cuts were similar ($p > 0.05$) and both samples were of acceptable microbiological quality (ranging between 4.15 - 4.70 log CFU g⁻¹ and 1.48 - 0.60 log CFU g⁻¹, respectively). Increase in TPC, LAB, and yeast-mold counts of the LT and LL samples were insignificant during the aging process ($p > 0.05$). *Enterobacteriaceae* counts were lower than the other microorganism groups and were not different ($p > 0.05$) between the cuts. At the end of the dry aging, the TMAC, TPC, LAB, and yeast-mold counts were similar ($p > 0.05$) for both cuts. Our previous study showed that dry aging had no significant effect on TMAC, TPC, LAB, and yeast-mold.¹⁶ Also, the decrease in bacterial growth might have been caused by surface drying during dry aging.²⁹

In summary, this study showed that dry aging improved the quality of both cuts of lamb meat. A 7-day dry aging process was sufficient to produce the desired sensory properties in lamb loins. Increasing the dry aging period from 7 to 14 days did not considerably affect the sensory features or tenderness. An increase in the aging time of lamb loins had no significant effect on tenderness or the sensory qualities of the meat. LL cuts were more suitable for dry aging according to the shear force, weight loss and sensory panel results. Results suggested that dry aged lamb loins had potential as a value-added product for meat industry.

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Conflicts of interest

The authors have no conflicts of interest.

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