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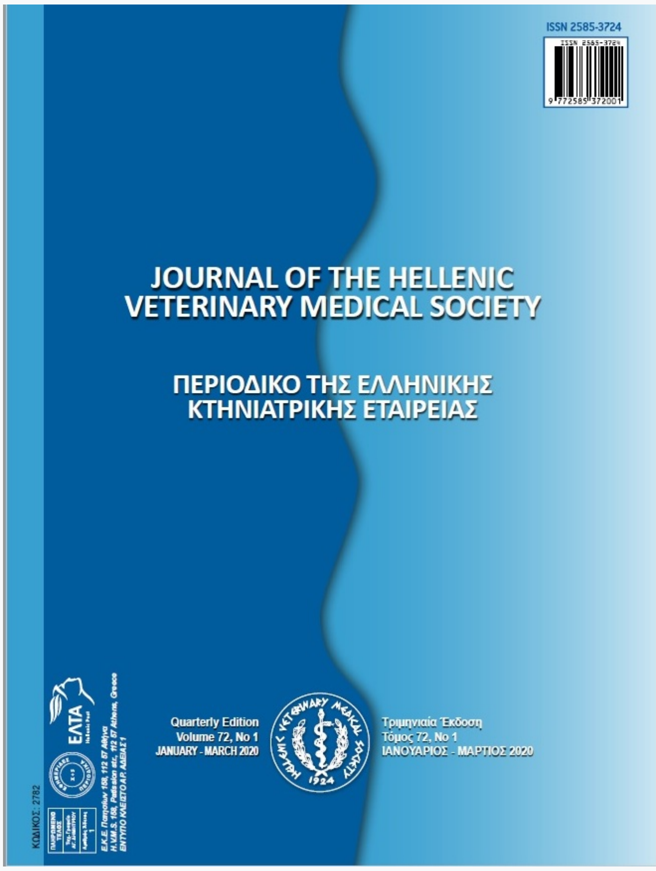

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Research article
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Determination of the alterations in quality parameters and consumer preference of dry-aged beef based on different periods of ageing using a purposive incubator

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ABSTRACT: The aim of this study was to evaluate beef quality traits including pH, water holding capacity, cooking loss, meat colour, and Warner-Bratzler shear force in dry-aged beef and to determine the most favorable ageing time based on beef quality parameters and consumer acceptability. In this respect, longissimus dorsi samples were obtained from Simmental bulls and stored for an ageing period up to 21-days, and thus, the beef quality evaluation was performed at 0-day, 7-day, 14-day, and 21-day of the experimental period. Results revealed that the lowest shear force value was observed in beef samples on day-14 whereas the lowest pH value was determined in samples on day 21. Moreover, water holding capacity and beef colour values were significantly differentiated based on dry-ageing ($P<0.05$). In sensory panel evaluation, a significant difference is found only in meat colour rating ($P<0.05$). There was no significant difference between ageing periods and cooking loss. The most important technical point is that increasing dry-ageing time from 14 to 21 days did not desirably affect quality traits and sensory scores. Hence, dry-ageing for 14 days seemed to be the most economically efficient application. Taken altogether, the present results suggest that the potential for use of dry-ageing should be considered as an alternative method to produce high-quality beef with respect to the optimum ageing process.

Keywords: *Beef, dry ageing, consumer preference, sensory characteristics, meat quality*

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INTRODUCTION

Beef tenderness and palatability are important issues for consumers which can directly influence their acceptance. Ageing meat is one of the most important applications performed to increase the tenderness over time and to enhance the palatability of the product. Moreover, it is obviously required for the development of flavors because true beef flavor is fully developed after approximately 11 days of ageing (Oreskovich et al., 1988; Sitz et al., 2006).

In general, there are two methods of ageing including wet- and dry-ageing (Laster et al., 2008). Beef predominantly sold in food stores is vacuum packaged and aged in a vacuum-bag. This technique is called wet-ageing and it is applicable for 7 to more than 21 days post mortem. A relatively small amount of beef is dry-aged, usually for 14 to 30 days post mortem (Stenström et al., 2014). Dry ageing is the ageing application of carcasses or retail cuts in a refrigerated room or a cooler, where storage temperature, humidity, and air flow are controlled (Sitz et al., 2006; Smith et al., 2008; Dashdorj et al., 2016). The post mortem process of physiological regulation in muscle structure is complex. During the dry ageing period, the key factor is to concentrate the special dry-aged beef flavor. This can only be provided by the juices that are absorbed into beef, biochemical reactions of protein and fat components that enhances the flavor properties. As a result, the enzymatic catalysis leads to more tender beef (Campbell et al., 2001; Dashdorj et al., 2016).

Enhanced flavor and desired palatability characteristics provide the perception of a premium product to dry-aged beef. This situation results in higher prices for dry-aged beef products in the marketplace (Laster et al., 2008). Thus, most dry-aged beef is sold by upscale restaurants, speciality shops or internet and it can be difficult to attain the products in ordinary restaurants or food stores (Stenström et al., 2014). On the other hand, as demand for dry-aged beef increases, the technique of dry ageing has raised its economical importance in meat industry and the food service market. As mentioned above, controlling the storage temperature, humidity, and air flow during the dry ageing process is essential for achieving desired characteristics of dry-aged beef. Recently, specific coolers for dry-aged meat have been developed to provide an optimum ageing process which is easily containable under storage conditions. The majority of earlier studies on the ageing of beef have compared wet ageing and dry ageing with respect to the product quality and consumer sensory preference (Campbell et al., 2001; Laster et al., 2008; Smith et al., 2008; Li et al., 2014; Stenström et al., 2014). However, there are inconsistencies and even contradictions within an optimum ageing time for dry-aged beef. Therefore the aim of this study was to determine beef quality properties and sensory characteristics of beef using a dry ageing incubator and to compare the quality parameters based on different periods of ageing. Furthermore, the consequences for the acceptance by consumers were evaluated.

MATERIALS AND METHODS

Sampling and ageing process

Beef samples were obtained from Simmental bulls (n=3) which were 16 months old and were slaughtered at 610 kg on the same day at a commercial abattoir according to standard practices. Twelve pairs of *m. longissumus dorsi* (obtained from both the left- and right-side from a carcass) were selected for use as samples for evaluation of quality parameters. Primary samples (n=24) were cut transversely at the mid-length (approx. 20 cm in length). Initially, analyses of beef quality parameters including beef colour, water holding capacity (WHC), cooking loss (CL), and Warner-Bratzler shear force (WBSF) were applied to fresh beef samples (as indicated by day 0, control group). Afterwards, the remaining sections were each dry-aged for 7, 14, and 21 days using a dry ageing incubator (Frenox DR6-G, Devon, United Kingdom). Dry ageing was performed for 7, 14 and 21 days at temperature of 2.20 ± 0.40 ºC. Humidity averaged 87 ± 4.60% during the entire experimental period. No ultraviolet lights were used. Regarding all beef quality parameters, three times-repeated measurements were performed and the average was evaluated as the final value for each sample.

pH and weight losses

In order to measure pH values of each sample, a digital pH meter (Testo 205, Lenzkirch, Germany) was used after the calibration with pH 4.01 and pH 7.00 standard buffer solutions (Testo) at 2–4°C. Measurements were conducted in triplicate at random points of each sample. Initially, samples were weighed using an analytical balance (Radwag AS220/C/2, capacity 220 g, readability 0.10 mg, Bracka, Poland), and then cooked in a 75°C water bath (Nuve BM 302, Turkey) for 60 minutes. After cooling in running tap water for 60 minutes, their packages were opened, beef samples were dried with filter paper to remove excess moisture and weighed again. Ultimately, CL was estimated as a percentage of weight of the samples before and after cooking, according to the following formula: (weight before cooking – weight after cooking) / weight before cooking × 100(Pietrasik and Duda, 2000). The WHC of beef samples was measured by the Grau and Hamm procedure (Grau and Hamm, 1957) and it was considered as the ratio of moisture kept in the sample to the initial moisture content (Pietrasik and Duda, 2000). Briefly, a meat sample weighing 5 g was placed on 10 cm diameter filter papers between two petri plates and was pressed under 2.250 kg for 5 min. Following the removal of the filter papers and the weight, WHC, as a percentage, was calculated as (final filter weight – initial filter weight) / meat sample weight × 100.

Beef colour

The colour of beef samples was measured using a reflectance colourimeter Konica Minolta CM508d (Konica–Minolta Inc., Ramsey, NJ, USA). Samples at least 12 to 15 mm thick were used to absorb non-reflected light. Colour parameters were evaluated based on the CIELAB system with colourimetric coordinates L^* (lightness), a^* (redness), and b^* (yellowness) regarding standard illumination, D65 and 10° standard observer. The device was calibrated with a standard white plate provided by the manufacturer and it was set to make three measurements to take their average. This instrumental evaluation allows beef colour to be expressed in a three dimensional space. Along the a^* axis, *a* positive a^* represents red, and *a* negative a^* represents green (scale from +60 for red to −60 for green). Along the *Y* axis, *a* positive b^* represents yellow, and *a* negative b^* represents blue (scale from +60 for yellow to −60 for blue). The third dimension L^* is represented numerically where 100 is white, and 0 is black (Hunt et al., 2012). Three-times-repeated colour measurements were performed from each beef sample of the cut surface and the mean of these measurements was assigned as the final value. Colour measurements were taken so that connective and fat tissue was avoided.

Shear force analysis

After the corresponding ageing time (7, 14, and 21 days) beef samples were prepared for WBSF analysis. The samples cooked for the measurement of CL were used to determine shear force value. Three cylindrical cores (surface area: approx. 1×1 cm, core length: min. 30 mm) parallel to the longitudinal alignment of the muscle fibres were sheared across the widest dimension by using an universal testing machine (Zwick/Roell Z0.5, Germany) equipped with a V-shaped Warner-Bratzler blade with a 60° triangular aperture (Ekiz et al., 2009).WBSF value of each sample were determined by taking the average of the measurements obtained from three cylindrical cores. The device was set to 150 mm/min crosshead speed and 50 kg force (applied to sample). Data were collected with the software provided by the manufacturer.

Consumer sensory panel

Taste panel members (n=17) were chosen among academicians at the Bursa Uludag University Faculty of Veterinary Medicine in Bursa, Turkey. Participants were not to eat or drink for one hour prior to the test. They were also instructed to rinse their mouths with water and to smell the ground coffee before tasting began as well as between samples. Prior to assessment, samples were wrapped individually in aluminium foil and assigned a three-digit code. They were cooked at 200°C using a pre-heated double-plated electric oven (Nuve FN 120, Turkey). Afterwards, the coating fat and connective tissue were removed, they were cut into cubic subsamples (20×20×10 mm) and were kept warm in a heater at 60°C until the taste panel assessment (Gill et al., 2009; Resconi et al., 2010). The panellists scored the beef samples on a 1–8 scale for seven traits, odour, flavour, tenderness, juiciness, colour, general acceptance, and overall liking as described by Gill et al.(2009) with some modifications. Each panelist received three cubes of each sample of four treatments (0 day-control, and dry aged for 7, 14, and 21 days) and thus evaluated 12 samples in the same environmental conditions. Samples were characterized using hedonic scales for beef odour (8=like extremely, 1=dislike extremely), level of beef flavour (8=extremely intense, 1=extremely bland or no flavour), intensity of the tenderness (8=extremely tender, 1=extremely tough), level of juiciness (8=extremely juicy, 1=extremely dry), beef colour (8=like extremely, 1=dislike extremely), general acceptance (8=extremely desirable, 1=extremely undesirable, abnormal flavour or odour), overall like (8=like extremely, very definitely would purchase, 1=dislike extremely, very definitely would not purchase).

Statistical analysis

Measurements were performed in triplicate, and the obtained results were statistically analysed using the SPSS v23.0 (IBM, Armonk, NY, USA). Testing homogeneity of variances was performed with Levene's test. The data of beef quality parameters were considered as repeated measures (day 0 and 7, 14, and 21 day dry-ageing treatments) and analyzed by using Friedman's test. Post hoc analysis was carried out using Dunn's test.

RESULTS

pH, WBSF, WHC, and weight loss

There was a significant effect of dry ageing on pH, WBSF, and WHC ($P<0.05$), as shown in Table 1. WBSF and WHC were higher in samples at day 0 compared to dry-aged samples. It is worth noting that dry-aged beef at 14th day had the lowest shear force value (2.61 N/mm). The highest pH was observed in samples at day 7. There was no significant effect of ageing on CL.

Instrumental beef colour

The ageing time had significant effects on all beef colour parameters studied ($P<0.05$). In this context, the L^* value prominently decreased after 21 days of ageing, and accordingly, the lowest L^* value was determined at the 21st day of dry ageing period (32.47±2.99). Similarly, this period of ageing was significantly associated with the lowest a^* and b^* values ($P<0.05$). The highest L^* and b^* values were determined on day 0, whereas, the highest value was observed in day 7.

Sensory panel

The influence of dry ageing treatments on consumer preference is shown in Table 2. The only statistical difference among samples that were dry-aged for different lenghts of time was for colour score ($P<0.05$). Panellists valued day-14 samples significantly higher than other ageing groups with respect to beef colour (Table 2). The greater sensory ratings (based on odour, flavour, tenderness, juiciness, general acceptance, and overall liking scores) for the samples at day 14 contributed to the greater value compared to samples at day 0, 7, and 21. However, this result was not statistically substantiated ($P>0.05$).

Table 1. Means and their corresponding standard deviations (SD) for pH, Warner–Bratzler shear force values, water holding capacity, cooking loss, and beef colour parameters of beef steaks stratified by dry-ageing periods

Traits	Day 0		Day 7		Day 14		Day 21		Significance
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
pH	5.020^{ab}	0.032	5.207^{a}	0.028	5.081^{ab}	0.049	4.890^{b}	0.240	$P<0.05$
WB shear force (N/mm)	11.328^{a}	0.866	8.297^{b}	0.941	2.610^{c}	0.010	6.687^{b}	0.577	$P<0.05$
Water holding capacity	0.660^{a}	0.118	0.190^{ab}	0.094	0.145^{ab}	0.045	0.080^{b}	0.008	$P<0.05$
Cooking loss (%)	11.550	0.136	8.740	0.021	10.080	0.086	9.00	0.510	NS
L^* (lightness)	45.610^{a}	3.820	40.150^{a}	1.001	43.507^{a}	0.927	32.47^{b}	2.990	$P<0.05$
a^* (redness)	17.944^{ab}	2.425	20.003^{a}	1.691	13.653^{ab}	0.535	3.053^{b}	1.105	$P<0.05$
b^* (yellowness)	14.432^{a}	2.451	15.260^{a}	1.250	12.470^{a}	0.481	3.407^{b}	1.366	$P<0.05$

WB: Warner Bratzler.

a,b,c Different superscripts within a row indicate significant difference.

Table 2. Means and their corresponding standard deviations (SD) for consumer sensory evaluation (n = 17 panellists) for steaks stratified by dry-ageing periods

Traits	Day 0		Day 7		Day 14		Day 21		Significance
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Odour	5.150	1.549	6.067	1.486	6.601	1.352	5.733	1.580	NS
Flavour	4.950	1.588	5.867	1.356	6.200	1.612	6.133	1.767	NS
Tenderness	4.383	1.637	6.067	1.387	6.600	1.765	5.800	1.568	NS
Juiciness	4.183	1.589	5.933	1.486	5.943	1.668	5.333	1.759	NS
Colour	5.483^{b}	1.589	5.801^{b}	1.424	6.733^{a}	1.335	5.533^{b}	1.506	$P<0.05$
General acceptance*	4.950	1.702	6.200	1.474	6.533	1.506	6.133	1.685	NS
Overall liking	5.033	1.677	6.067	1.486	6.600	0.400	5.933	1.624	NS

*General acceptance was evaluated as the presence of abnormal flavour or odour as indicated by Gill et al. (2009).

a,b Different superscripts within a row indicate significant difference.

DISCUSSION

In the present study, alterations in beef quality parameters were evaluated with respect to samples at 0, 7, 14, and 21 day. Dry ageing method was applied to all samples and the evaluations were performed based on pH, weight losses, WBSF, instrumental colour, and sensory panel. Obviously, the importance of these traits varies according to both attributes of the final product and the consumer choices(Koohmaraie and Geesink, 2006). In many countries, the primary objective of beef production has gradually changed from beef yield to quality. Especially in affluent countries, consumers usually request meat products which are of the high quality. Although there are obvious problems in beef production in many countries (concerning the balance between supply and demand), high quality meat products are increasing its perceived importance. Hence, the different techniques of beef ageing and their economical significance in meat industry should be evaluated in a more detailed and systematic way. In this perspective, this study presents an elaborate analysis of quality parameters of dry-aged beef with respect to ageing time alterations. Due to the significance of quality parameters, various attempts have been made to ensure these parameters of beef when presented to the consumer. Of these beef quality parameters, tenderness is ranked as the most important (Miller et al., 2001; Koohmaraie and Geesink, 2006). Thus, recent studies have tended to focus efforts on evaluating the basis for beef tenderness, primarily because of its economic significance. A wide variation in degree of postmortem tenderization is evident, and hence, the inconsistency of meat tenderness is a prevalent circumstance at the consumer level (Miller et al., 2001; Koohmaraie and Geesink, 2006; Warner et al., 2010). It is worth noting that dry ageing improves WBSF and sensory-panel scores of tenderness (Campbell et al., 2001; Ahnström et al., 2006). This interpretation was substantiated, at least in part, in the present study. WBSF values were significantly affected by dry-ageing process and the beef at day 14 was the most tender ($P<0.05$). Shear force analysis indicated an obvious increase in corresponding values for day 21 (Figure 1). Moreover, although statistically insignificant, the samples from this type of beef had the highest sensory-panel scores of tenderness (6.60). These results are in accord with the study conducted by Campbell et al. (2001) who suggested that increasing dry ageing time from 14 to 21 day did not appreciably influence flavour or tenderness. Beef colour evaluation also indicated a sharp decrease in the L^*, a^*, and b^* values for 14 to 21 day dry ageing period (Figure 2). Moreover, the 21-day dry-aged beef was significantly associated with the lowest values for pH and WHC ($P<0.05$). In this study, no statistical differences among treatments for CL were found to demonstrate the effectiveness of the dry-ageing time. These results are of great importance for practical applications, because they allow the implementers in beef sector to decide the optimum dry-ageing with maximum profit.

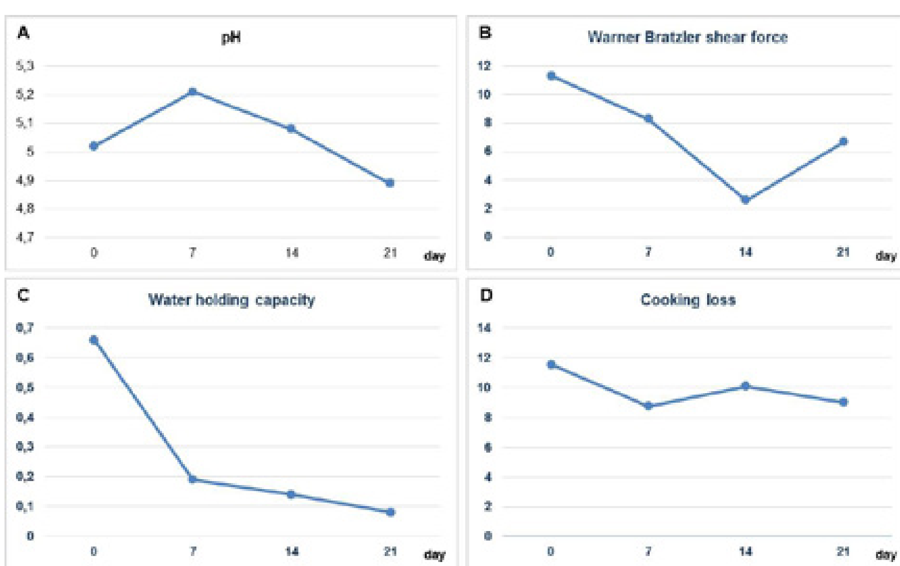

Figure 1. Changes in beef quality parameters including pH, Warner Bratzler shear force (N/mm), water holding capacity, and cooking loss (%) during 21 days of dry-ageing

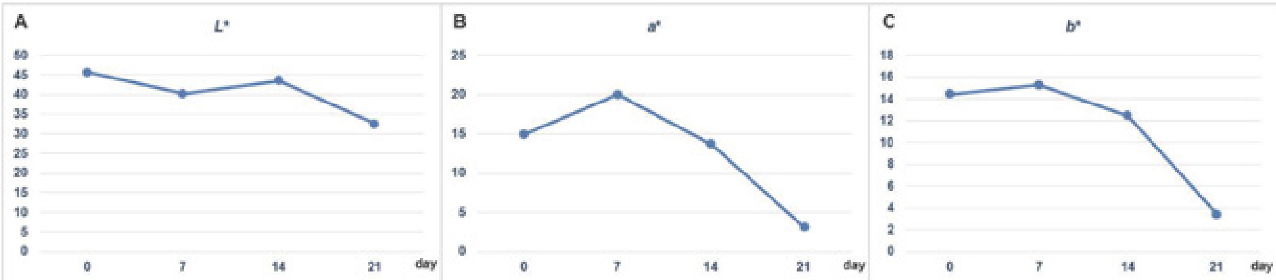

Figure 2. Changes in beef colour parameters during 21 days of dry-ageing

Beef quality is affected by many factors including genetics, management, pre-and post-slaughter factors (Warner et al., 2010). Moreover, evaluation of beef quality through ageing process is complex one. Flavour, juiciness and tenderness influence the palatability of meat and these parameters directly affect the consumer perceptions which include both visual and sensory traits (Koohmaraie and Geesink, 2006; Warner et al., 2010). In the present study, results clearly demonstrated that the most desirable beef is 14-day dry-aged for which panellists gave higher rankings (6.60, 6.20, 6.60, 5.94, 6.53, and 6.60 for odour, flavour, tenderness, juiciness, general acceptance, and overall liking, respectively). However, the only statistical difference among samples was for colour score (P<0.05). The samples at day 14 (6.73) had +1.25, +0.932, and +1.20 higher means of colour score compared to samples at day 0, 7, and 21, respectively. One possible explanation for decrease in colour scores at day 21 may be the higher metmyoglobin percentage at the surface of beef under modified atmosphere after 21 days of dry-ageing together with the decrease that was observed in redness.Beef colour is one of the most important quality parameters because it directly influences the consumer's buying decision (Ardicli, 2018), and thus, evaluation of colour preferences may be crucially important for dry-aged beef which is offered in mostly fine restaurants, upscale grocery stores and gourmet steak companies. Here it should be noted that the application of dry-ageing is usually for 14 to 30 days post mortem (Stenström et al., 2014). Dry ageing process generally improves flavour, sensory, and textural attributes(Warren and Kastner, 1992; Campbell et al., 2001). Increase in dry aged beef flavour is related to several chemical interactions involving proteins, lipids and carbohydrates. In this respect, this particular improvement of the flavour may be relevant to releasement of free amino acids, peptides, reducement of sugars, and the breakdown of ribonucleotides during postmortem ageing. In addition, carbohydrates broken down into sugars can ultimately give sweet taste, while degradation of fats and fat like membrane molecules may contribute to beef aroma (Dashdorj et al., 2016). These chemical alterations give concentration of flavor to dry aged beef. Moreover, during dry ageing process, the natural enzymes in the beef may provide desirable tenderness levels (Warren and Kastner, 1992). However, our study showed that dry ageing for more than 14 days appears to be inadequate with respect to beef quality analyses and sensory panel results.It is apparent that the development of beef quality is a highly dynamic process. Continuing activity of the endogenous hydrolases and proteolytic enzymes which have different substrate specificities and pH optima during the post-mortem ageing period and tenderization process constantly changes the quality parameters and flavor components (Spanier et al., 1997). Improper quality parameters of beef dry-aged for 21 days may be attributed to undesired chemical alterations in the level of numerous reactive chemicals and intermediates during the postmortem ageing period (Warren and Kastner, 1992; Spanier et al., 1997; Dashdorj et al., 2016). Moreover, interactions and reactions between chemical components including peptides and free amino acids, carbohydrates, organic acids, and metabolites of adenine nucleotide metabolism such as ATP are most likely to contribute to the significant results obtained from the present study for 14 days dry-ageing application.

Dry ageing of beef is a costly procedure because of decreased yields due to greater weight, trim losses and time consuming processing (Dashdorj et al., 2016). It is important to note that, a longer ageing time is suggested to be associated with increase in trim loss and decrease in microbiological quality (Ahnström et al., 2006; Karaduman et al., 2018). Therefore, decision on the dry-ageing time seems to be a crucial point to achieve a profitable process.

CONCLUSIONS

Consequently, data from the current study demonstrated that dry ageing process partially enhanced beef quality traits including shear force, colour, particularly colour scores as determined by the sensory panel. A significant improvement in WBSF values for samples at day 14 was also observed. The most important point in the present evaluation is that increasing dry-ageing time from 14 to 21 day did not desirably affect beef quality traits and sensory scores. On the contrary, this period was associated with a sharp decrease in quality parameters. Dry ageing did not adversely impact CL. Of interest for those processors who may plan to attend dry-aged beef applications, this study suggests that dry ageing till 14 days would provide more economically favourable process. On the long view, this implementation may be crucial in dry ageing applications because long period of ageing beef is obviously associated with high risk of contamination, trim loss, ageing shrinkage, requirements of ageing conditions and space. Considering the raise of demand high quality beef products, such as dry-aged beef, studies focusing on this processing need to be performed because corresponding results and recommendations on ageing conditions may help companies, retailers or upscale restaurants who aim to produce a dry aged beef.

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CONFLICT OF INTEREST STATEMENT

None of the authors of this article has any conflict of interest.

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