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Effect of different aging methods and periods on physical and chemical beef qualities from *Longissimus thoracis*

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Abstract The results showed that the aging method and aging period significantly ($p<0.05$) affected aging loss, trimming loss, and cooking loss. Aging loss and trimming loss of DA and DB beef were higher than those of WV and WS beef ($p<0.05$). However, cooking loss in WV and WS beef was higher than DA and DB beef. No significant differences ($p>0.05$) were observed among aging methods in pH, colour (L*, a*, and b*), Warner-Bratzler shear force (WBSF), lipid oxidation (TBARS). Prolonged aging time (up to 4 weeks) resulted in more tender meat, while lipid oxidation increased ($p<0.05$). Additionally, beef colour changed significantly with increasing aging time ($p<0.05$). There were not different in percentage of fat, dry matter, ash, or moisture among aging method. However, DA and AB beef showed higher percentage of protein than WV and WS beef ($p<0.05$). These findings can be applied to develop for beef industry, particularly small-scale beef retailers and restaurants businesses, could be enhance value of premium grade beef in Thailand.

Keywords: Beef quality, Dry aging, Fat oxidation, Tenderness, Wet aging

Introduction

The global demand for beef consumption is increasing, as beef is a major source of nutrients and highly palatable to consumers (Paolo *et al*., 2023). Beef aging has become particularly popular in Asian countries, especially in high-end restaurants that feature aged beef on their menus (Zuljargal *et al*., 2023). Tender beef is in high demand among consumers and can be sold a higher price (Kim *et al*., 2022).

Currently, there are several technologies used to enhance tenderness of meat. Post-slaughter meat processing techniques, especially aging, are well-established as critical factors for improving tenderness, flavor, and overall

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acceptance (Ha *et al*., 2019). Beef aging is a traditional method that involves either hanging carcass or vacuum packaging of sub-primal or portion cuts for controlled periods of refrigerated storage. Aging serves as a value-adding process and has been widely accepted by consumers and the global meat industry for many years (Kim *et al*., 2016; Kim *et al*., 2018). However, in Thailand, there is limited in-depth research comparing different aging methods, including dry aging and wet aging.

Dry aging involves hanging or suspending meat in a controlled environment with temperature, relative humidity, and air velocity for several weeks. The circumstance for dry aging must be precisely controlled and continuously monitored to prevent microbial proliferation and reduce weight loss (Kim *et al*., 2022). Although dry aging improves meat tenderness and enhances its aroma and flavor (Zuljargal *et al*., 2023), prolonged aging results in weight loss due to moisture evaporation. To address this, dry aging in bags method has been developed. Wet aging, on the other hand, involves vacuum-sealing meat and held under cooling storage, which prevents moisture loss, maintains tenderness, and reduces microbial contamination. However, wet aging is less preferred by consumers due to its shorter aging period and less desirable flavor, juiciness, overall liking, and satisfaction scores compared to dry aging (Holman *et al*., 2022).

As the demand for aged beef in Thailand has grown rapidly and become more popular, it has become a premium product in the market, commanding in higher price. To reduce beef imports and enhance the competitiveness of domestic beef, it is essential to increase the value of lower quality beef with less intramuscular fat. Aging is a key method to achieve this by improving tenderness and meeting market demands. Therefore, the objective of this study aimed to compare the effects of different aging methods that are dry aging, dry aging in bag, wet aging in a vacuum bag, and wet aging in a shrink bag at various aging periods on the physical and chemical qualities of beef.

Materials and methods

Meat samples and sample preparation

This experiment was approved for the use of meat samples in scientific research by The Animal Care and Use Committee, King Mongkut’s Institute of Technology Ladkrabang, under approval document number CC-KMITL/2026/003.

Meat samples used in this experiment were obtained from three female crossbred cattle (Holstein Friesian×Angus), approximately five years old. The live body weights prior to slaughter ranged from 600 to 750 kg. The cattle were raised under the production system of the KU-Beef Cooperative. The animals were slaughtered under standard commercial procedures in accordance with animal welfare regulations at the slaughterhouse of the

Research and Development Center for Animal Production, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom Province.

After slaughter, the carcasses were aged at 0-4°C for seven days. *Longissimus thoracis* muscle samples, still attached the bone and fat, were collected from the left and right sides of carcass between the 6th and 12th ribs. The intramuscular fat (marbling) score of the samples was evaluated and found to be level 2. The samples were then placed in sealed bags and transported in foam boxes with ice to maintain temperature during delivery to the Animal Meat Technology Laboratory.

A schematic representation of the randomized sampling design for beef muscles collected from left and right carcass sides is presented in Figure 1. The longissimus muscle portions were divided into 5 pieces per side using band saw, each approximately 15 cm thick and weighing about 2.5-3 kg. Each muscle was sectioned from anterior to posterior, with portions randomly assigned to aging periods of 0, 2, or 4 weeks across three independent replications.

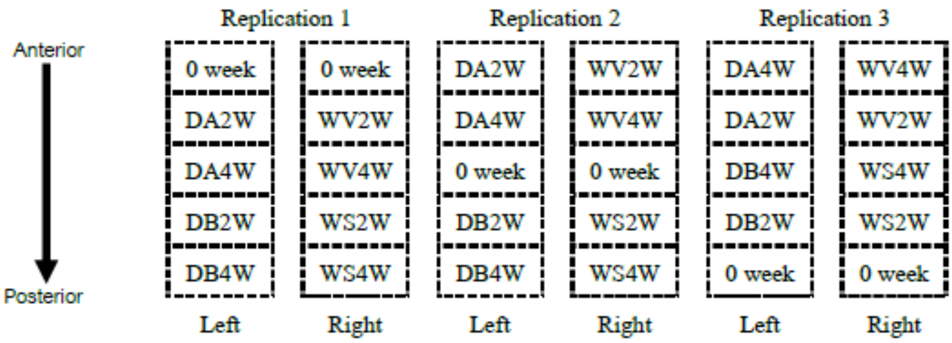

Figure 1. Schematic of portioning and random allocation of carcass muscles sampling for physical and chemical quality assessment across three aging times (0, 2, and 4 weeks). DA = dry aging, DB= dry aging in bag, WV = wet aging in a vacuum bag, and WS = wet aging in a shrink bag

Aging method

Four aging methods were used in this study: dry aging, dry aging in bag, wet aging in a vacuum bag and wet aging in a shrink bag. In the first method, dry aging, sections of longissimus muscle with bones were placed in an aging cabinet under controlled conditions: a temperature of 0-4°C, air velocity of 0.5 m/sec, and relative humidity of 75-80%. In the second method, dry aging in bag, beef sections were placed in UMAi DryR Short Loin (Large) bags, which are permeable to oxygen and moisture. The samples were then aged in the same aging cabinet under the controlled conditions. For the third method, wet aging in a vacuum bag, the meat sections were vacuum sealed in EVOH/Nylon/PE bags and stored in the aging cabinet under the same controlled conditions. For the fourth method, wet aging in a shrink bag, sections of longissimus muscle were vacuum sealed in EVOH/Nylon/PE bags and subsequently submerged in hot water at 95ºC to shrink the bags. The samples were then aged under the same controlled conditions in the aging cabinet.

The aging cabinet used in this study was developed by Associate Professor Samak Rakmae from the Department of Agricultural Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang. This aging cabinet was modified from Sanden intercool model YR-1500SRT refrigerator to control temperature (0-4 ºC), air velocity (0.5 m/sec), and relative humidity (75-80%).

Physical properties analysis methods

pH measurement

The pH of beef samples was measured using a pH meter (Mettler Toledo model SG-2, Switzerland). Each sample was measured in triplicate.

Colour measurement

The surface of the longissimus muscle sections was trimmed to expose the meat to oxygen for approximately 30 minutes prior to colour measurement. Colour analysis was performed using the CIE (L*, a*, b*) colour system with a HunterLab Mini Scan EZ 4500S colorimeter (Hunter Lab Inc., USA). Each sample was measured at three different locations. Measurements were reported as L*, a*, and b* values, representing lightness, redness and yellowness, respectively.

Chroma and Hue angle

The chroma (colour saturation) and hue angle were calculated using the a* and b* values obtained from the colorimeter, following the method described by Saricoban and Yilmaz (2010). The formulas used were as follows:

$$\text{Chroma} = \sqrt{(a^{*2}/b^{*2})} \quad (1)$$

$$\text{Hue angle} = \tan^{-1}(b^*/a^*) \quad (2)$$

Shear force

The tenderness of beef samples was evaluated by measuring shear force using a Warner-Bratzler shear device. Samples were cut into strips measuring 2.5 x 1 cm along the direction of the muscle fibers. Shear force was measured using an Instron machine (model 3344, USA) device. The results were recorded following the method described by Van Moeseke and De Smet. (1999).

Aging loss (%)

The weight loss during aging was calculated as a percentage of the initial weight. The initial weight (A) and the final weight after aging (B) were recorded following the method described by Stolowski *et al*. (2006). The percentage of weight loss was calculated using the following equation:

$$\text{Weight loss (\%)} = [(A - B) / A] \times 100 \quad (3)$$

Trimming loss (%)

The weight loss after trimming crust on the surface (approximately 0.5 cm thick) was calculated as a percentage of the initial weight. The initial weight (A) and the final weight after trimming (B) were recorded following the method described by Oreskovich *et al*. (1988). The percentage of weight loss was calculated using the following equation:

$$\text{Trimming loss (\%)} = [(A - B) / A] \times 100 \quad (4)$$

Cooking loss (%)

The weight loss after cooking was calculated as a percentage of the initial weight. The initial weight (A) and the final weight after cooking (B) were recorded following the method described by Cummings *et al*. (1999). The percentage of weight loss was calculated using the following equation:

$$\text{Cooking loss (\%)} = [(A - B) / A] \times 100 \quad (5)$$

Chemical properties analysis methods

Chemical composition

- Moisture: AOAC (2016) method 945.39
- Ash: AOAC (2012a) method 942.05
- Protein: Inhouse method: TI-C00-016 based on ISO 5983-2:2005
- Fat: Inhouse method: TI-C00-015 based on AOAC (2012b) 920.39

Lipid oxidation (TBARS)

Lipid oxidation was determined using the Thiobarbituric Acid Reactive Substances (TBARS) assay, following a modified method from Cooper *et al*. (2018). Samples were homogenized, filtered and analysed using a UV-VIS spectrophotometer (UV-1601, Shimadzu Corporation, Japan) at a wavelength of 532 nm. The concentration of malondialdehyde (MDA) was calculated based on a standard calibration curve, and results were expressed as mg MDA/kg of sample.

Statistical data analysis

Data were analyzed using a Completely Randomized Design (CRD). Statistical analysis of variance (ANOVA) was applied, and treatment means were compared by Duncan's Multiple Range Test (DMRT) at a significant level of $p<0.05$ using SPSS software.

Results

Physical quality of beef using different aging methods

The physical quality of beef *Longissimus thoracis* results are shown in Table 1. The study indicated that significantly different among aging methods were found in cooking loss, aging loss, and trimming loss ($p<0.05$). Dry aging (DA) and dry aging in bag (DB) resulted in lower cooking loss compared to wet aging in a vacuum bag (WV) and wet aging in a shrink bag (WS). The highest of aging loss and trimming loss were observed in DA method, followed by DB, WS and WV, respectively ($p<0.05$). The percentage of aging loss were 18.56, 12.37, 1.88 and 1.64, respectively. The percentage of trimming losses were 22.51, 18.62, 11.52 and 14.25, respectively. Meanwhile, there were no significant differences ($p>0.05$) in pH value, color traits (L*, a*, b*, Chroma and Hue angle), and Warner-Bratzler shear force (WBSF).

Regarding the effect of aging time on meat quality, the results revealed that longer aging periods influenced the values of a*, b*, chroma, hue angle, WBSF, cooking loss, aging loss, and trimming loss ($p<0.05$). Extended aging time caused a significant reduction in a* and chroma values in beef, regardless of the aging method. The b* value was significantly higher in 2 weeks of age compared with 0 and 4 weeks. Moreover, prolonged aging up to 4 weeks resulted in a significant increase in the hue angle value. The WBSF and cooking loss significantly decreased ($p<0.05$) with longer aging in all methods, whereas cooking loss and trimming loss of beef increased. However, aging period did not affect pH and L* values ($p>0.05$).

Chemical quality of beef using different aging methods

Chemical composition

The results of proximate analysis are presented in Table 2. There was no significant difference in the percentage of fat, dry matter, ash, or moisture contents among aging methods. However, DA and DB beef showed a higher protein percentage than WV and WS beef. The moisture content in DB, WV and WS was slightly higher than DA, but the difference was not statistically significant ($p>0.05$). Extending the aging period up to 2-4 weeks affected proximate analysis values. Prolong aging significantly reduced percentage of moisture content ($p<0.05$). Conversely, percentage of dry matter, protein and fat were significantly increased ($p<0.05$). Additionally, percentage of ash decreased in dry ageing beef (DA), while significantly increased ($p<0.05$) in beef aged in bag (DB, WV, and WS).

Lipid oxidation (Thiobarbituric acid reactive substance: TBARS)

In this comparative study of beef aging methods (DA, DB, WA, and WS), no significant effect on lipid oxidation values (TBARS) was observed at any aging time for up to 4 weeks. Additionally, at the 4th week of beef aging, it was found that dry aging beef had higher TBARS values compared to other methods (0.73, 0.51, 0.47, and 0.37, respectively). However, the difference was not statistically significant (P>0.05).

As the beef aging period increased (2 and 4 weeks), all aging methods showed higher TBARS with significantly increased (p<0.05) after aging for 4 weeks. In addition, dry aging methods displayed the highest TBARS levels as shown in Table 3.

Table 1. Physical quality traits of beef *Longissimus thoracis* under different aging methods and aging times

Parameters	Aging time (wk)	Aging methods[1/]			
		DA	DB	WV	WS
pH	0	5.68±0.05	5.68±0.05	5.70±0.06	5.70±0.06
	2	5.93±0.17	5.77±0.13	5.70±0.11	5.71±0.05
	4	5.69±0.10	5.73±0.06	5.71±0.03	5.66±0.09
L*	0	30.02±0.65	30.02±0.65	31.38±1.19	31.38±1.19
	2	30.82±1.84	30.59±0.89	31.96±2.22	31.73±1.57
	4	32.00±4.99	32.19±2.37	33.09±4.29	34.02±2.78
a*	0	19.39±1.25^{A}	19.39±1.25^{A}	17.62±2.54^{A}	17.62±2.54^{A}
	2	17.21±2.59^{AB}	17.85±2.97^{AB}	17.94±2.64^{AB}	15.55±2.08^{AB}
	4	13.83±2.00^{B}	14.80±3.69^{B}	16.99±2.58^{B}	16.72±2.22^{B}
b*	0	15.81±0.84^{AB}	15.81±0.84^{AB}	15.12±1.13^{AB}	15.12±1.13^{AB}
	2	16.37±3.03^{A}	16.29±2.46^{A}	16.64±2.03^{A}	15.37±1.71^{A}
	4	14.62±4.22^{B}	14.80±2.15^{B}	15.30±3.49^{B}	14.50±1.57^{B}
Chroma	0	25.03±1.34^{A}	25.03±1.34^{A}	23.24±2.67^{A}	23.24±2.67^{A}
	2	23.69±4.06^{AB}	24.00±3.99^{AB}	23.96±3.48^{AB}	21.31±2.82^{AB}
	4	18.61±2.78^{B}	21.74±0.73^{B}	22.88±4.24^{B}	22.14±2.72^{B}
Hue angle	0	39.23±1.59^{B}	39.23±1.59^{B}	40.63±1.78^{B}	40.63±1.78^{B}
	2	43.92±3.67^{A}	42.41±2.46^{A}	41.34±0.47^{A}	42.99±0.83^{A}
	4	41.80±3.99^{A}	42.82±1.63^{A}	41.68±2.47^{A}	40.97±0.91^{A}
WBSF (kg)	0	5.70±0.33^{A}	5.70±0.33^{A}	6.39±0.60^{A}	6.39±0.60^{A}
	2	5.23±0.45^{B}	5.18±0.55^{B}	5.57±0.66^{B}	5.54±0.51^{B}
	4	4.64±0.64^{C}	4.67±0.69^{C}	4.93±0.60^{C}	4.83±0.78^{C}
Cooking loss (%)	0	28.80±2.82^{b,A}	28.80±2.82^{b,A}	30.13±3.47^{a,A}	30.13±3.47^{a,A}
	2	28.05±0.85^{b,A}	28.60±0.30^{b,A}	30.62±0.38^{a,A}	30.40±0.63^{a,A}
	4	27.07±0.99^{b,B}	27.72±0.55^{b,B}	28.38±2.31^{a,B}	28.21±0.19^{a,B}
Aging loss (%)	2	11.66±0.05^{a,B}	9.87±0.94^{b,B}	1.22±0.29^{c,B}	1.52±0.10^{c,B}
	4	18.56±1.41^{a,A}	12.37±1.96^{b,A}	1.64±0.19^{c,A}	1.88±0.01^{c,A}
Trimming loss (%)	2	19.66±1.48^{a,B}	15.83±2.09^{b,B}	9.99±1.67^{d,B}	12.88±0.88^{c,B}
	4	22.51±2.70^{a,A}	18.62±1.15^{b,A}	11.52±1.52^{d,A}	14.25±0.38^{c,A}

Results are presented means±SD

$^{a-d}$ Means with different superscripts in the same row significantly differ (p<0.05)

$^{A-C}$ Means with different superscripts in the same column significantly differ (p<0.05)

1/: DA = dry aging, DB= dry aging in bag, WV = wet aging in a vacuum bag, WS = wet aging in a shrink bag

Table 2. Proximate composition (%) of beef *Longissimus thoracis* under different aging methods and aging time

Parameters	Aging time (wk)	Aging methods[1/]			
		DA	DB	WV	WS
Moisture (%)	0	61.19±0.33^{A}	61.19±0.33^{A}	62.25±0.37^{A}	62.25±0.37^{A}
	2	59.52±1.10^{B}	60.22±0.26^{B}	61.58±1.15^{B}	60.45±0.52^{B}
	4	57.80±1.79^{C}	58.82±2.53^{C}	60.31±0.53^{C}	59.52±1.55^{C}
Dry matter (%)	0	38.81±0.19^{C}	38.81±0.19^{C}	34.75±0.21^{C}	34.75±0.21^{C}
	2	40.48±0.92^{B}	39.78±0.17^{B}	38.42±0.53^{B}	39.55±0.40^{B}
	4	42.20±1.79^{A}	41.18±2.53^{A}	39.69±0.53^{A}	40.48±1.55^{A}
Ash (%)	0	6.12±0.05^{a,B}	6.12±0.00^{a,B}	6.76±0.04^{b,A}	6.76±0.04^{b,A}
	2	5.26±0.07^{c,A}	6.48±0.16^{b,A}	6.28±0.12^{a,B}	6.20±0.40^{b,B}
	4	5.73±0.95^{c,A}	6.85±0.40^{b,A}	6.11±0.09^{a,B}	6.19±0.29^{b,B}
Protein (%)	0	21.01±0.16^{a}	21.01±0.16^{a}	20.04±0.55^{b}	20.04±0.55^{b}
	2	21.26±0.56^{ab}	21.22±1.92^{a}	19.89±0.75^{b}	20.41±2.14^{ab}
	4	21.49±2.12^{ab}	22.93±0.47^{a}	20.17±2.83^{b}	20.32±1.62^{ab}
Fat (%)	0	16.93±1.87^{B}	16.93±1.87^{B}	17.77±0.56^{B}	17.77±0.56^{B}
	2	16.17±2.59^{B}	17.51±3.41^{B}	19.98±1.77^{B}	20.41±2.14^{B}
	4	19.31±1.89^{A}	21.05±4.34^{A}	20.20±1.01^{A}	21.29±0.34^{A}

Results are presented means±SD
$^{a-c}$ Means with different superscripts in the same row significantly differ ($p<0.05$)
$^{A-C}$ Means with different superscripts in the same column significantly differ ($p<0.05$)
1/: DA = dry aging, DB= dry aging in bag, WV = wet aging in a vacuum bag, WS = wet aging in a shrink bag

Table 3. Lipid oxidation (TBARS, mg MDA/kg) of beef *Longissimus thoracis* under different aging methods and aging time

Aging time (wk)	Aging methods[1/]			
	DA	DB	WV	WS
0	0.28±0.10^{B}	0.28±0.10^{B}	0.24±0.08^{B}	0.24±0.08^{B}
2	0.34±0.19^{AB}	0.51±0.45^{A}	0.33±0.16^{AB}	0.34±0.13^{AB}
4	0.73±0.73^{A}	0.51±0.33^{A}	0.47±0.28^{A}	0.37±0.15^{A}

Results are presented means±SD
$^{A-C}$ Means with different superscripts in the same column significantly differ ($p<0.05$)
1/: DA = dry aging, DB= dry aging in bag, WV = wet aging in a vacuum bag, WS = wet aging in a shrink bag

Discussion

Physical quality

In this study, no significant differences in meat colour, pH and Warner-Bratzler shear force were observed among aging methods. Aging loss and trimming loss were higher in DA and DB beef than in WV and WS beef. However, cooking loss was higher in beef subjected to both wet aging methods (WV and WS beef) compared to dry aging methods (DA and DB beef). Additionally, beef colour changed significantly with increasing aging time ($p<0.05$). Contrary to the findings of previous studies, which reported that the pH was higher in dry-aged beef than in wet-aged beef loins, all colour parameters (L*, a*, b*) of dry-aged beef and beef aged in a bag were lower than those of wet-aged beef. Dry-aged beef and beef aged in a bag also exhibited a slightly darker, less red, and less yellow colour. These differences could be associated with moisture loss during the dry aging process. Dehydration of dry-aged meat reduces light reflection and concentrates colour components, including myoglobin and iron, resulting in changes in meat colour. These results are consistent with other studies, which have shown that colour parameters decrease with increasing aging time (Ha *et al*., 2019; Ribeiro *et al*., 2021; Zhang *et al*., 2021; Kim *et al*., 2022).

Generally, prolong aging time results in lower WBSF values, with dry aging beef exhibiting lower WBFS compared to wet aging beef (Lee *et al*., 2019; Kim *et al*., 2022). The results of this experiment are supported by many studies indicating that storage loss, trimming loss, and aging loss in dry aging beef increase with aging time. On the other hand, the lowest aging loss has been observed in wet aging beef (Kim *et al*., 2022).

Chemical qualities

There were no significant differences found in the percentage of fat, dry matter, ash, or moisture among the aging methods. However, DA and DB beef showed a higher protein percentage of protein than WV and WS beef. This finding aligns with other studies that reported that there is no difference in moisture content between wet aging and dry aging (Ahnström *et al*., 2006: DeGeer *et al*., 2009). Kim *et al*. (2017) also supported this result, that the moisture content of beef aged for 20 days did not significantly different ($p>0.05$) between dry aging and wet aging meat. Similarly, Zhang *et al*. (2021) demonstrated that dry aging lamb had higher protein content compared to wet aging lamb. Kim *et al*. (2017) reported that after aging for 20 days and 40 days, protein content of dry aging beef and wet aging beef increased ($p<0.05$).

In this experiment, the moisture content in DB, WV, and WS beef was slightly higher than in DA beef, but the difference was not statistically significant ($p>0.05$). This contradicts the findings of Zhang *et al*. (2021), who reported that the moisture content in dry aging lamb was significantly lower than wet aging lamb ($p<0.0001$). This could be explained that dry aging meat generally dehydrates on outer surface of meat. Most studies trim the surface crust of dry aging meat prior to sampling for moisture content analysis, thereby eliminating the differences that would otherwise be observed.

TBARS is widely used to investigate of lipid oxidation in meat and meat products by measuring the content of lipid peroxidation products, such as malondialdehyde (MDA) found in the samples. Lipid oxidation in meat and meat products can produces MDA which is one of products from rancidity and reaction with TBA. As this result, other deteriorate properties such as colour of meat and meat products also can be changed (Grotta *et al*., 2017; Zhang *et al*., 2021; Kim *et al*., 2022).

The results of this experiment (Table 3) indicated that TBARS value tended to lower in wet aging beef, while the highest TBAR values were found in dry aging beef. However, the differences were not statistically significant ($p>0.05$). Many studies have reported that dry aging beef generally reveals the highest TBARS values compared to beef age in the bag or wet aging beef in vacuum bags. This is due to dry aging beef exposing directly to oxygen, which accelerates lipid oxidation and leads to higher TBARS values. In bag dry aging beef is moisture and oxygen permeable but still control by the bag, which can reduce lipid oxidation compared to traditional dry aging. Wet aging typically packed in vacuum bag results in the lowest TBARS values due to lack of oxygen in their environment.

In this experiment had done aging time for 4 weeks, which may explain why TBARS values were not significant different ($P>0.05$). To obtain more distinct results, it is recommended to extend aging time. Many studies have used aging time of 40-60 days (Lee *et al*., 2019; Kim *et al*., 2022; Zuljargal *et al*., 2023).

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Conflicts of interest

The authors declare no conflict of interest.

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