Meat and Muscle Biology™

Effects of Wet Aging, Dry Bag Aging, and Stepwise Aging Methods on Meat Quality and Sensory Attributes of Steaks From Pasture and Grain Finished Steers

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Abstract: The study aimed to evaluate the effect of 2 finishing diets (F: pasture or grain) and 4 meat aging methods (AM) on physicochemical traits, microbiological loads, and sensory attributes of beef, with aging methods as follows: wet aging (WA) for 40 d; dry aging in the bag (DAb) for 40 d; dry bag for 20 d + wet 20 d (DW); and wet 20 d + dry bag 20 d (WD). Sixty striploins, consisting of the right and left *Longissimus lumborum* (LL) muscle, from British crossbred steers, were employed, with 15 pairs of striploins obtained from pasture-finished and 15 pairs from grain-finished diet. Meat from grain-finished steers was lighter (greater L^* values; $P < 0.01$) than from those finished on pasture. Meat aged using DAb presented lower cooking loss values ($P < 0.01$) than WA. Stepwise WD aging increased Psychrotrophic organisms (PSY) and total bacterial count (TBC) ($P < 0.05$) compared to the other 3 treatments. No AM * F interaction on the physicochemical characteristics (color, pH, cooking losses, and shear force) and the surface microbiological load was observed ($P > 0.05$) except for a^* and b^* coordinates of lean color. There was a significant AM * F interaction effect on the fatty acid composition for conjugated linoleic acid (CLA; c9, t11-18:2), saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acid (PUFA), and PUFA n6. Greater concentrations of PUFA, PUFA n6, and CLA ($P < 0.01$) were observed in all AM treatments from pasture-finished and in WD from grain-finished steers; meanwhile, SFA and MUFA were greater in DW and WD from grain-finished animals ($P < 0.05$). A greater PUFA:SFA ratio ($P < 0.05$) and lower n6:n3 ratio ($P < 0.01$) were found in pasture-finished than in grain-finished steers. Consumers preferred tenderness, flavor, and overall liking from DAb and WA samples ($P < 0.05$) over WD steaks. AM had the greatest influence on the physicochemical and microbial properties, while the finishing diet primarily affected the fatty acid composition and consumer preferences. All aging methods were acceptable to consumers, but combining wet and dry aging in a bag did not enhance sensory appeal.

Keywords: beef, finishing diet, stepwise aging, dry aging bag, meat quality attributes
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Introduction

It is well-recognized that aging is a postmortem practice for tenderization and flavor improvement of beef (Campbell et al., 2001; Smith et al., 2008; Kemp et al., 2010; Ba et al., 2016). In the meat industry, wet and dry aging are the most common processes to age beef. Wet aging involves placing meat into a plastic bag, which acts as a barrier to moisture loss. Bags are vacuum-sealed and stored at refrigerated temperatures (−1 to 2°C) for a specified length of time (Smith et al., 2008). Dry aging is a traditional

aging method that exposes unpackaged meat to cooling conditions with strict temperature (0–4°C), relative humidity (RH; 80–85%), and airflow control (0.5–2 m/s) (Dashdorj et al., 2016). A third alternative is dry aging in a highly moisture-permeable bag, widely used in recent decades (Ahnström et al., 2006; Li et al., 2013; Zhang et al., 2019; Zhang et al., 2020). The adoption of water-permeable aging bags to produce dry-aged products is mainly to reduce microbial contamination, lipid oxidation, and trim loss when compared to the traditional out-of-bag dry-aging technique (DeGeer et al., 2009; Ahnström et al., 2006; Zhang et al., 2020). Kim et al. (2018) reported that savory/beef flavor increases during aging (particularly dry aging) because of flavor-related compound liberation. Another technique that combines the methods previously mentioned, dry aging in a bag with wet aging (stepwise process), is proposed since it produces microbiologically safe dry-aged beef compared to traditional dry-aged meat with maximized saleable meat yield (Zhang et al., 2019) maintaining traditional dry aging savory/beef flavor.

Carcass composition and eating quality attributes of beef meat are known to be influenced by the finishing diet (del Campo et al., 2008; Peripolli et al., 2018; Correa et al., 2020). Several studies have reported that different nutritional-management approaches have shown that animals finished on high-concentrate diets displayed heavier carcasses and improved beef quality attributes such as tenderness, marbling, ribeye area, and backfat thickness than pasture-finished animals (Realini et al., 2004; Duckett et al., 2013; Ferrinho et al., 2020). Conversely, pasture-finished animals produced beef with lower concentrations of fat and cholesterol and a higher percentage of n3 polyunsaturated fatty acids (PUFA) and conjugated linoleic acid (CLA) than grain-finished animals (Aldai et al., 2011; Duckett et al., 2013; Brito et al., 2014; Ferrinho et al., 2020). Previous research (Melton, 1983; Nuernberg et al., 2005; Ha et al., 2019) reported that the greatest difference in the development of flavors of meat from cattle finished on pasture or grain is due to the concentration and composition of fatty acid as they are the primary source of aromatic compounds such as carbonyls.

In an international market where meat eaters are looking for new experiences and more intense flavors, it is important to investigate alternatives to fresh meat that are more attractive to them. It needs to be considered that eating quality differences between dry and wet aging have been consistently attributed to higher flavor and aroma intensities (Iida et al., 2016; Kim et al., 2016). Therefore, a marketing alternative to expanding the range of fresh meat products would be to implement dry aging methods (dry aging bag) to capitalize on its benefits, to meet the expectations of more demanding consumers. We hypothesize that the dry aging bag and wet aging combination improve the physicochemical and organoleptic properties of the meat, adding the benefits of both aging methods compared to each method applied on its own.

Therefore, this study aimed to evaluate the effect of two different aging methods: dry bag aging (DAb) and wet aging (WA), and their combinations of DAb followed by WA (DW) and WA followed by DAb (WD), in meat from pasture-finished and grain-finished steers on physicochemical, microbiological, and consumer acceptance of sensory beef attributes.

Materials and Methods

Raw materials and aging process

This study was carried out complementary to Correa et al. (2024), and the duplicities of the experimental design and sample set are acknowledged. Striploins (*m. Longissimus lumborum* [LL], paired loins, $n = 60$) were obtained from 30 steers (under 30 mo of age; British crossbred) finished (F) in a pasture ($n = 15$) or grain ($n = 15$). Animals raised on pasture are qualified for the Hilton quota and comprise select cuts from steers or heifers, ensuring the production of high-quality beef exclusively raised on pasture, following the Uruguayan grading system. Conversely, animals from grain feeding systems qualify for the European Union 481 quota and consist of beef cuts from carcasses of steers and heifers under 30 mo of age, finished on a diet containing no less than 62% of concentrates for a minimum of 100 d before slaughter. They were slaughtered in a commercial meat processing plant (hot carcass weight: 266.5 kg and 253.2 kg pasture and grain, respectively). Steers from the same commercial farm were selected considering age, live weight, and fat cover (INAC, 1997) to set up two similar groups. Thirty striploins (left and right LL) of each F system were obtained for analysis and assigned to an aging method. Both striploin of each carcass were divided into pieces, and the most cranial piece (10 cm) of each striploin was assigned to combined aging: 20 d dry aging bag followed by 20 d wet aging (DW) and 20 d wet aging followed by 20 d dry aging bag (WD). The remaining left striploin was divided into 2 pieces and assigned randomly to one of the following treatments: 40 d dry aging bag (DAb, 16 cm) and 40 d wet aging (WA, 14 cm), ensuring half

of each treatment in each position of the striploin (caudal and cranial). The remaining right striploin was used for another study. The pH measurement was inserting the pH probe (HI 99163, Hanna Instruments Inc., Hoonsocket, USA) directly into the beef loin sections initially and at the end of the aging period. Dry aging was performed using a TUBLIN® bag (10 and 50 µm thick, polyamide mix with a water vapor transmission rate of 2.5 kg/50 µ/m^2/24 h at 38°C, 50% RH, TUB-EX ApS, Denmark), while a Cryovac® bag was employed for wet aging (50 µm thickness; maximum oxygen transmission rate of 27 cm^3/m^2/24 h at 22 to 24°C and 0% RH and moisture vapor transmission rate of 5 g/m^2/24 h at 38°C and 90% RH; Cryovac® Sealed Air Corp., BB 2620, Brazil).

Striploin pieces were placed on racks in a chilling chamber (at 2 ± 0.5°C and RH of 85 ± 5%) during the aging period. Temperature and RH were monitored using 3 dataloggers (Electronic Temperature Instruments Ltd., UK), to obtain real-time information at different points inside the chamber. The air velocity was recorded weekly at different chamber positions with a digital anemometer (HoldPeak 866A digi, China) averaging 0.5 m/s. Meat pieces were relocated on the racks into the chamber every week to prevent any potential confounding effect of location within the cooler.

Instrumental color

One steak per loin section (DAb, WA, DW, and WD) was cut at the end of the aging period (40 d) and exposed to bloom for 45 min at 4°C (King et al., 2023). The surface color was measured using a Minolta Chroma Meter CR-400 (Konica Minolta Sensing Inc., Japan) calibrated using a standard white tile. CIE $L^*a^*b^*$ (Commission Internationale de l'Eclairage, 1976) color space values: L^* (lightness), a^* (redness), and b^* (yellowness) were taken (Illuminant C, 2-grade standard observer, 8 mm of opening size) per triplicate on the lean surface of each steak. Values were averaged to obtain a mean for each sample. Total color change (Delta E) between treatments was calculated as $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{0.5}$ (King et al., 2023).

Cooking losses and Warner-Bratzler shear force

The same steaks (2.5 cm thick) used for color measurement were used for the cooking losses (CL) and the Warner-Bratzler shear force (WBSF). They were weighed before and after cooking to determine the CL according to the American Meat Science Association protocol (AMSA, 2016). Steaks were cooked in a grill (GRP100 The Next Grilleration, Spectrum Brands, Inc., Miami, FL) until the internal core temperature reached 71°C. The CL percentage was calculated with the following equation: ((raw weight − cooked weight)/raw weight) × 100.

After cooking, the steaks were cooled (5°C) for 12 h. Warner-Bratzler shear force (kg) was evaluated on 6 cores of 1.27 cm diameter from parallel to the longitudinal muscle fiber orientation using a hand-held coring device. The cylinders were sheared using a TA-XT Plus texture analyzer (Stable Micro System Ltd., UK) set with a "V" Warner-Bratzler slot blade and 8 mm/s speed. Shear force values resulted from the average of the 6 cores per steak.

Fatty acid composition and thiobarbituric acid-reactive substances

A second steak per loin section (DAb, WA, DW, and WD) was cut at the end of the aging period (40 d) for the intramuscular fat content (IMF), fatty acid composition, and lipid oxidation evaluation. The IMF was assessed using the lipid extraction method outlined by Bligh and Dyer (1959) involving chloroform-methanol, followed by the analysis of the fatty acid composition. Methylation of the fatty acids was carried out utilizing cold methanolic potash (IUPAC, 1987), and analysis was conducted via gas chromatography using a Shimadzu Nexis GC 2030 (Tokyo, Japan) instrument. Fatty acids were separated using a 60-meter SH-Rt-WAX capillary column (0.25 mm internal diameter, 0.25 µm film thickness, Shimadzu, Columbia, Maryland, USA), with nitrogen employed as the carrier gas at a flow rate of 1 ml/min.

A 1 µl injection volume was used with a flame ionization detector (FID). The detector temperature was maintained at 260°C, while the injector temperature was set to 230°C. The temperature ramp proceeded as follows: starting at 100°C for 0.5 min, it increased at a rate of 10°C/min until reaching 120°C for 2 min, then continued increasing at 10°C/min until reaching 220°C for 15 min, totaling 29.5 min per sample. Fatty acids were identified by comparing retention times with a standard mixture of 37 FAME SupelcoTM 37 compounds (Sigma, St. Louis, USA), while CLA (c9, t11-18:2) was identified using an octadecadienoic acid, conjugated, methyl ester standard (No. O5632, Sigma, St. Louis, Missouri, USA). Fatty acid content was reported in mg/100 g of meat using methyl heneicosanoate (C21:0) as an internal

standard (1 ml of 1 mg), which was added before the addition of methylating reagents.

Lipid oxidation was assessed using the thiobarbituric acid-reactive substances (TBARS) method, as modified by Ahn et al. (1998). Briefly, minced samples of 5 g were homogenized with 15 ml of deionized distilled water (DDW) using a tissue homogenizer (Wisd, HG-15A, Daihan Scientific) for 30 s. One milliliter of the meat homogenate was transferred to a disposable test tube (13 × 100 mm), and 50 µl of butyrate 16 hydroxyanisole (7.2%) and 2 ml of thiobarbituric acid/trichloroacetic acid (TBA/TCA) solutions were added. The mixture was vortexed and then incubated in a boiling water bath for 15 min for color development. The TBARS samples were cooled down in the ice bath for 10 min before centrifugation for 15 min at 1789 × g. The supernatant solution was collected, and the absorbance was determined at 531 nm against a blank containing 1 ml DDW and 2 ml TBA/TCA solution. Standard curves of malonaldehyde (MDA) were prepared using 1,1,3,3-tetra-ethoxypropane. The amount of TBARS was expressed as milligrams of MDA per kg of meat.

Surface microbial counts

A third steak was cut at the end of the aging period (40 d) for the surface microbial count. The impact of aging treatments on microbial surface growth was assessed by measuring total bacterial count (TBC), Psychrotrophic microorganisms (PSY), and Enterobacteriaceae (ENT) concentrations. Microorganisms from the untrimmed surface of a 1.5 cm steak taken from the extreme of each piece were enumerated on day 0 and day 40 after the aging period. Individual beef samples (4 × 4 cm square) were aseptically excised from the center of 10 steaks per treatment using disposable scalpels (Feather Sterile Scalpels 2975#21; Graham-Field Inc., Atlanta, GA) and placed into individual sterile Whirl-Pak bags (710 ml, 15 × 23 cm, 0.102 mm thick; Nasco Int., USA). The 4 × 4 cm squares were placed into a stomacher bag (BagMixer® 400 P, Interscience, Saint Nom, France) and homogenized with 90 ml of 0.1% peptone water (Oxoid, UK) for 2 min for microbial analysis. The appropriate dilutions were surface-plated in duplicate onto 2 sets of Petrifilms (3M, Uruguay): one set was used for TBC enumerations and the other for enumerating PSY. Dilutions were also duplicated onto a set of Petrifilm surfaces (3M; Uruguay) for enumeration of the ENT microbial population. For a clear identification, the Petrifilms were enumerated according to the treatments, before incubation at 37°C for 48 h for TBC or 7°C for 10 d for PSY and 37°C for 24 h for ENT.

Consumer sensory testing

The fourth steak, cut after 40 d of aging, was for consumer sensory testing. Meat samples were cooked in a grill (GRP100 The Next Grilleration, Spectrum Brands, Inc., Miami, FL) until the core (internal) temperature of the steak reached 71°C (AMSA, 2016). Once cooked, steaks were trimmed of external fat and connective tissue and cut across the grain into a 1.3 × 1.3 × 2.0 cm piece, wrapped individually in coded aluminum foil, assigned to a cup, and kept warm in a heater/oven at 49°C for no more than 10 min until being tasted. Sensory evaluation was conducted by a Uruguayan consumer panel with 10 sessions of 10 consumers each ($n = 100$). Each consumer evaluated 8 samples, on 2 dishes, each with 4 samples, 2 from each finishing system and 2 aging methods (WA/DAb or WD/DW), and the order of the dishes was alternated among sessions. Moreover, the order of sample presentation for each consumer and dish was designed to avoid the first sample and carry-over effect (MacFie and Bratchell, 1989). Water and unsalted crackers were provided to consumers as palate cleansers. Before tasting, consumers were asked to answer a questionnaire with demographic (gender, age range, education level) and frequency in the consumption of different types of meat, as well as to sign the consent form if they agreed to participate (Table S1, Supplementary data). Each consumer was asked to score each sample in terms of acceptability of tenderness, flavor, and overall liking using a 9-point hedonic scale, as follows: 1 for "I like it extremely", 2 for "I like very much", 3 for "I quite like it", 4 for "I like it", 5 for "I neither like nor dislike", 6 for "I dislike it", 7 for "I quite dislike it", 8 for "I dislike very much", and 9 for "I dislike it extremely".

Data analysis

The experimental design was a split-plot, where each finishing diet served as a main plot (F: pasture or grain) and carcasses (pair of loins) served as sub-plot for the aging methods (AM: DAb, WA, DW, and WD). The model included the fixed effects of F and AM, with their interactions, and the random effect of carcasses. These were analyzed using the MIXED procedure in SAS software (v. 9.4, SAS Institute Inc., Cary, NC, US). Data were checked for normality using the UNIVARIATE procedure and, when necessary, were

normalized with a log10 transformation. The least-squares mean (LSM) was calculated, and means separation was performed ($P < 0.05$) using the PDIFF option. Peak cooking temperature was used as a covariable for WBSF and CL analysis.

For sensory evaluation, tenderness, flavor, and overall liking, scores were analyzed using a model that included the fixed effects of AM, F, and their interaction, and consumers were considered random effects. The tasting session was considered a blocking factor. It was carried out by CLUSTER to find groups of consumers in a segmentation with similar preferences since when considered as a pool, differences are diluted, and they are difficult to determine. The CLUSTER procedure was performed by segmentation applying Euclidian distance and the Ward method. The number of clusters to retain was based on the obtained dendrogram, considering the homogeneity within and among the segments and the principle of parsimony. An analysis of variance was carried out, considering fixed effects, AM and F, and their interaction for the pooled sample and by cluster. A Tukey test was applied to find differences between LSM. Significance was fixed at $P < 0.05$.

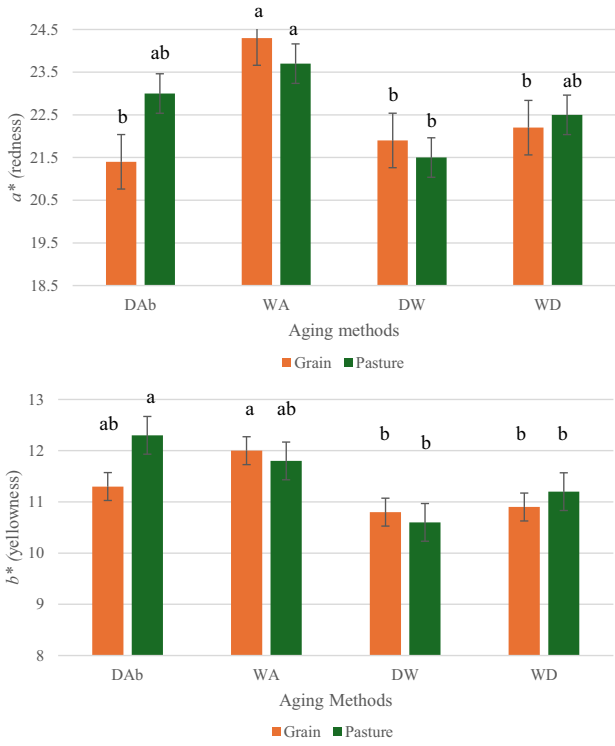

Figure 1. Interaction between aging methods and finishing diet on a^* and b^* color coordinates. DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + wet aging 20 d; WD; Wet aging 20 d + dry aging bag 20 d. Different letters denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

Results

Effects of aging method and finishing system on instrumental color, pH, cooking losses, and shear force

No interaction (AM * F; $P > 0.05$) was observed for the final pH, CL, WBSF, and L^* coordinate of meat color (Table 1). An interaction effect ($P < 0.05$) for redness (a^*) and yellowness (b^*) (Figure 1) indicated the greatest values of a^* in WA from grain-finished. In addition, for b^* coordinate the greatest value was in DAb from pasture-finished. Lightness (L^*) values were greater in WA than in DAb samples ($P < 0.05$), and no differences were found between both stepwise AM treatments ($P > 0.05$) presenting intermediate values not significantly different for WA or DAb (Table 1). Meat color from grain-finished steers resulted in lighter (greater L^* values) than from pasture-finished animals ($P < 0.05$). Delta E indicated values from 1.0 between DAb and WD to 2.7 between WA and DW; the difference value in the finishing diet was 2.2. The ultimate

Table 1. Effects (mean ± SEM) of aging method (AM) and finishing diet (F) and their interaction (AM * F) on meat quality parameters

Aging (AM)							Finishing (F)				AM * F
Traits	DAb	WA	DW	WD	SEM	*P*-value	Pasture	Grain	SEM	P-value	*P*-value
L^*	40.5^{b}	41.8^{a}	40.9^{ab}	41.3^{ab}	0.4	0.033	40.0	42.2	0.4	<0.001	0.350
Delta E*	2.22	0	2.74	1.94	—	—	—	2.22	—	—	—
pH	5.77^{a}	5.73^{b}	5.71^{b}	5.74^{ab}	0.01	0.002	5.72	5.75	0.02	0.246	0.869
CL (%)	17.9^{c}	23.4^{a}	20.2^{b}	20.2^{b}	0.5	<0.001	20.6	20.2	0.5	0.593	0.246
WBSF (kg)	2.6	2.5	2.6	2.5	1.0	0.318	2.7	2.5	1.2	0.457	0.198

DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + WA 20 d; WD: Wet aging 20 d + Dry aging bag 20 d. CL: cooking losses; WBSF: Warner-Bratzler shear force. Different letters in the same row denote groups' statistically significant differences ($P < 0.05$) among LSMeans. L^* indicates lightness, and a^* and b^* are chromaticity coordinates. a^* and b^* are color directions: $+a^*$ is the red axis, $-a^*$ is the green axis, $+b^*$ is the yellow axis, and $-b^*$ is the blue axis.

*For Delta E calculations, WA was used as a reference.

pH values were greater ($P < 0.05$) in DAb than in WA and DW samples (Table 1). The CL was lower in DAb samples than the other 3 AM, and no differences were observed between DW and WD aging methods ($P > 0.05$), which were lower than WA. Warner-Bratzler shear force values did not differ among aging methods ($P > 0.05$). The finishing diet of the steers did not affect ultimate pH, CL, and WBSF values ($P > 0.05$) (Table 1).

Effects of aging method and finishing system on fatty acid profile and oxidation

No interaction (AM * F; $P > 0.05$) was observed in IMF (%), PUFA n3, n6:n3, and PUFA-to-saturated fatty acid (SFA) ratio (Table 2); the other fatty acids are presented in supplementary data (Table S2). After the aging period, DW presented higher IMF (%) values than WA, with intermediate values in DAb and WD ($P < 0.01$). Polyunsaturated fatty acid n3 and PUFA:SFA ratio increased and n6:n3 ratio decreased in pasture-finished steers ($P > 0.05$). The combination of aging methods and finishing diet impacted (AM * F; $P < 0.05$) most of the fatty acids (Figures 2 and 3, and in supplementary data Table S3). Saturated fatty acid and monounsaturated fatty acid (MUFA) presented the highest values in DW and WD from grain-finished steers ($P < 0.05$; Figure 3). In addition, PUFA (Figure 2) and CLA (Figure 3) presented the greatest content in pasture-finished regardless of treatments, and PUFA n6 in DAb from pasture (Figure 3). Although no interaction between aging methods and finishing diet was observed for the sum of PUFA n3, there was an interaction ($P < 0.05$) for C18:3n3 and C20:3n3. The linolenic acid (C18:3n3) presented the highest values in aging treatments from pasture-finished, and the eicosatrenoic acid (C20:3n3) did in DAb from pasture-finished and WD from grain-finished steers (Table S3). Regarding lipid oxidation, AM * F interaction (Figure 4; $P < 0.05$) was observed. Stepwise aging (WD) from grain-finished steer meat presented greater TBARS values than grain-finished DAb and all pasture-fed aging methods.

Effects of aging method and finishing system on superficial microbial counts

The meat samples analyzed before aging presented superficial microbial counts below the detection limit (<1 log/cm^2). There was no interaction AM * F effect ($P > 0.05$). The aging method affected the TBC ($P = 0.023$) and PSY ($P < 0.01$) load, where WD had the highest values, over the DAb, and finally WA and DW. No differences were observed for ENT load ($P = 0.105$). The finished diet had no significant effect ($P > 0.05$) on TBC, PSY, and ENT counts in meat aged by the different methods (Table 3).

Effects of aging method and finishing system on meat acceptability

Results of the consumer study are presented in Tables 4 and 5, considering all the consumers as a pool or segmented by clusters, respectively. Analyzing all consumers ($n = 100$), no interaction between AM and F was observed in any of the attributes evaluated ($P > 0.05$; Table 4). Regarding AM, the least preferred meat was WD for overall, tenderness, and flavor liking, and the most preferred were DAb and WA. On the other hand, meat from grain-finished steers was preferred compared to grass-finished animals. When all consumers are considered as a pool, the differences are diluted and are difficult to determine; therefore, the consumers were segmented into 3 clusters depending on their acceptability scores (Table 5). For Cluster 1 ($n = 31$), the lowest acceptability ($P < 0.05$) of meat was from DW and pasture diet for the 3 attributes. Cluster 1 could

Table 2. Effects (mean ± SEM) of the aging method (AM) and the finishing diet (F) and their interaction (AM * F) on intramuscular fat and the fatty acid profile

	Aging						Finishing				AM * F
Trait	DAb	WA	DW	WD	SEM	*P*-value	Pasture	Grain	SEM	*P*-value	*P*-value
IMF (%)	3.9^{ab}	3.7^{b}	4.2^{a}	4.0^{ab}	0.2	0.030	3.7	4.2	0.2	0.082	0.623
PUFA n3 (mg/100 g meat)	61.2	61.5	58.1	66.5	4.3	0.750	89.6	41.2	4.0	<0.001	0.053
n6:n3	3.1	2.9	3.1	3.0	0.17	0.477	2.1	4.5	0.23	<0.001	0.336
PUFA:SFA	0.12	0.12	0.11	0.12	0.007	0.377	0.14	0.10	0.01	0.006	0.083

DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + wet aging 20 d; WD; Wet aging + dry aging bag 20 d. IMF (%): Intramuscular fat; PUFA: sum of polyunsaturated fatty acid (PUFA n6 + PUFA n3); SFA: saturated fatty acid (C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 + C24:0); PUFA n3 (C18:3n3 + C20:3n3 + C20:5n3 + C22:5n3 + C22:6n3); PUFA n6 (C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6). Different letters in the same row denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

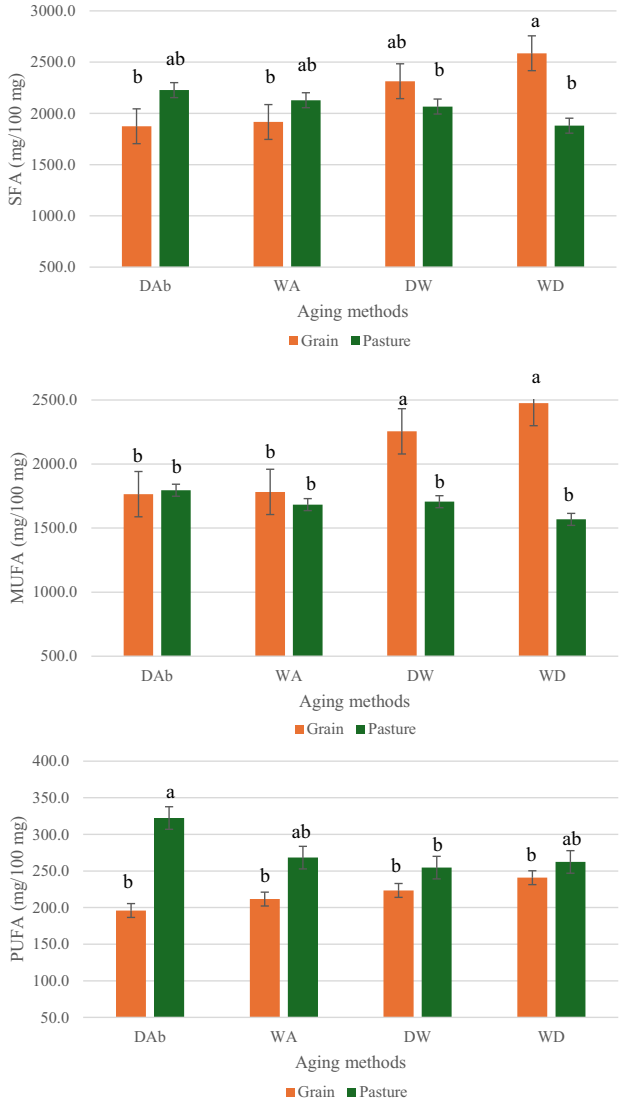

Figure 2. Interaction between aging methods and finishing diet on SFA, MUFA, and PUFA (mg/100 g meat). DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + wet aging 20 d; WD; Wet aging 20 d + dry aging bag 20 d. SFA: saturated fatty acid (C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 + C24:0); MUFA: monounsaturated fatty acid (C14:1 + C16:1 + C18:1n9); PUFA: sum of polyunsaturated fatty acid (PUFA n6 + PUFA n3); PUFA n3 (C18:3n3 + C20:3n3 + C20:5n3 + C22:5n3 + C22:6n3); PUFA n6 (C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6). Different letters denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

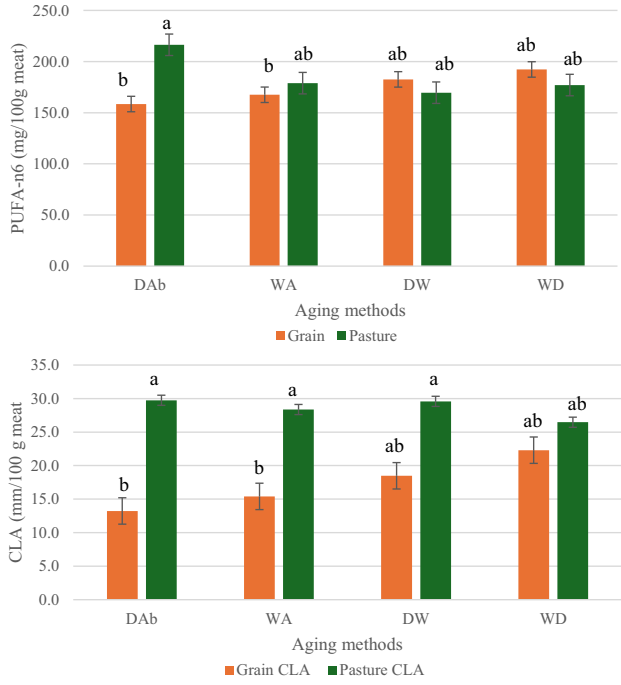

Figure 3. Interaction between aging methods and finishing diet on PUFA n6 and CLA (mg/100 g meat). DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + wet aging 20 d; WD; Wet aging + dry aging bag 20 d. CLA: conjugated linoleic fatty acid (*c*9, *t*11-18:2); PUFA n6 (C18:2n6 + C18:3n6 + C20:2n6 + C20:3n6 + C20:4n6). Different letters denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

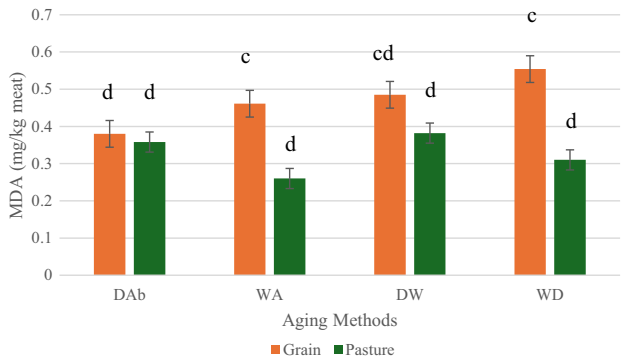

Figure 4. Interaction between aging methods and finishing diet on thiobarbituric acid-reactive substances (TBARS) concentrations (mg MDA/kg meat). DAb: Dry aging bag; WA: Wet aging; DW: Dry aging bag 20 d + wet aging 20 d; WD; Wet aging + dry aging bag 20 d. Different letters denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

be characterized by a higher preference for grain-finished steers and wet aging methods (WA, DW, and WD); thus they could be named "Grain-finished wet aging beef likers". For Cluster 2, the least preferred ($n = 27$) was WD from grain diet steers, for overall liking and flavor. Also, Cluster 2 could be characterized by a higher preference for grain-finished steers, especially those with DAb. They could be named "Grain-finished dry aged beef likers". In Cluster 3 ($n = 42$), the biggest group, the least preferred samples for overall and flavor liking came from WD and pasture. In contrast, the most preferred ones for overall acceptability were DW from pasture and WA from grain, and DW from pasture-fed steers for flavor liking. However, no important differences in scores have been found between samples, and most of them are within the "like it" score, making it difficult to classify them. Thus, they can be named "Undefined beef likers".

Table 3. Effects (mean ± SEM) of aging method (AM) and finishing diet (F) and their interaction (AM * F) on microbiological growth

	Aging						Finishing				AM * F
Trait	DAb	WA	DW	WD	SEM	*P*-value	Pasture	Grain	SEM	*P*-value	*P*-value
TBC (log_{10}/cm^2)	4.3^{ab}	3.9^{b}	4.1^{b}	4.6^{a}	0.19	0.023	4.3	4.2	0.17	0.837	0.361
PSY (log_{10}/cm^2)	5.4^{b}	5.0^{c}	5.0^{c}	6.5^{a}	0.11	<0.001	5.5	5.4	0.10	0.903	0.890
ENT (log_{10}/cm^2)	3.3	2.7	3.4	2.8	0.23	0.105	3.0	3.1	0.17	0.471	0.324

DAb: Dry aging bag; WA: Wet aging; DW; Dry aging bag 20 d+ Wet aging 20 d; WD; Wet aging 20 d + Dry aging bag 20 d. TBC: total bacterial count; PSY: Psychrotropic bacteria; ENT: Enterobacter bacteria. Different letters in the same row denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

Table 4. Effects (mean ± SEM) of aging method (AM) and finishing diet (F) and their interaction (AM * F) on sensory attributes (All consumers)

	Aging						Finishing				AM * F
Trait	DAb	WA	DW	WD	SEM	*P*-value	Pasture	Grain	SEM	*P*-value	*P*-value
Overall liking	3.6^{b}	3.4^{b}	3.6^{ba}	4.0^{a}	0.11	<0.001	3.8	3.5	0.1	<0.001	0.209
Tenderness	3.0^{b}	3.1^{b}	3.3^{ba}	3.6^{a}	0.12	<0.001	3.6	2.9	0.1	<0.001	0.196
Flavor	3.6^{b}	3.5^{b}	3.7^{b}	4.0^{a}	0.12	<0.001	3.9	3.6	0.1	0.015	0.780

DAb: Dry aging bag; WA: Wet aging; DW: dry aging bag 20 d + wet aging 20 d; WD: wet aging 20 d + dry aging bag 20 d. Scale 9 points: 1 "I like it extremely", 2 "I like very much", 3 "I quite like it", 4 "I like it", 5 "I neither like nor dislike", 6 "I dislike it", 7 "I quite dislike it", 8 "I dislike very much", and 9 "I dislike it extremely". Different letters in the same row denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

Table 5. Effects (mean ± SEM) of the interaction between the aging method (AM) and finishing diet (F) on sensory attributes according to the consumer clusters

	Pasture				Grain					Significance		
Trait	DAb	WA	DW	WD	DAb	WA	DW	WD	SEM	AM	F	AM * F
Overall liking												
Cluster 1	3.4^{b}	3.0^{bc}	4.5^{a}	3.5^{b}	3.7^{b}	2.5^{c}	2.6^{c}	3.2^{b}	0.2	<0.001	<0.001	<0.001
Cluster 2	3.0^{b}	3.1^{b}	2.6^{bc}	3.3^{ab}	2.0^{c}	2.4^{bc}	2.8^{b}	3.6^{a}	0.2	<0.001	0.039	0.002
Cluster 3	4.3^{b}	4.7^{b}	4.0^{b}	5.0^{a}	4.3^{b}	4.0^{b}	4.5^{ab}	4.5^{ab}	0.2	0.031	0.235	0.009
Tenderness												
Cluster 1	2.9^{bc}	3.2^{b}	4.2^{a}	3.4^{ab}	2.7^{bc}	2.2^{c}	2.5^{bc}	2.8^{bc}	0.2	0.025	<0.001	0.007
Cluster 2	2.4	2.9	2.9	3.1	1.8	1.9	2.4	2.8	0.2	0.002	<0.001	0.476
Cluster 3	4.1	4.3	3.8	4.1	3.3	3.4	3.6	4.5	0.2	0.026	<0.001	0.354
Flavor												
Cluster 1	3.4^{ab}	2.9^{b}	4.4^{a}	3.6^{ab}	3.6^{ab}	2.8^{b}	2.9^{b}	3.3^{b}	0.3	0.028	<0.001	<0.001
Cluster 2	3.2^{ab}	2.9^{bc}	2.6^{bc}	3.2^{ab}	2.2^{c}	2.5^{bc}	3.0^{b}	3.8^{a}	0.2	0.334	0.600	0.033
Cluster 3	4.2^{b}	4.6^{ab}	4.0^{b}	4.9^{a}	4.3^{ab}	4.1^{ab}	4.5^{ab}	4.5^{ab}	0.2	0.184	0.365	0.006

DAb: Dry aging bag; WA: Wet aging; DW: dry aging bag 20 d + wet aging 20 d; WD: wet aging 20 d + dry aging bag 20 d. Scale 9 points: 1 "I like it extremely", 2 "I like very much", 3 "I quite like it", 4 "I like it", 5 "I neither like nor dislike", 6 "I dislike it", 7 "I quite dislike it", 8 "I dislike very much", and 9 "I dislike it extremely". Different letters in the same row denote groups' statistically significant differences ($P < 0.05$) among LSMeans.

Discussion

Effects of aging method and finishing system on instrumental color, pH, cooking losses, and shear force

The results demonstrate that the aging method significantly influences most physicochemical traits, although WBSF was unaffected. The higher lightness (L^*) values observed in wet-aged (WA) samples may result from increased reflectance due to higher moisture retention (Bertram et al., 2004). This aligns with the hypothesis that water content affects light scattering on the meat surface, contributing to perceived brightness. The combination of aging methods (DW) showed intermediate L^* values, suggesting that partial moisture loss during dry bag aging modulates this property. Combining AM * F indicated that redness (a^*) values

were lowest in DAb samples from grain-fed cattle, followed by DW samples from both finishing diets. This might be attributed to the lower water content from the dry bag aging process and lower absorption on the meat's surface appearing dark red (Kim, 2011). The parameter b^* (yellowness) exhibited trends similar to a^*, with lower values in DW and WD samples regardless of diet. While this is consistent with prior findings (de Faria Vilella et al., 2019), it contrasts with studies that reported no differences in b^* between aging methods (Kim et al., 2017; Zhang et al., 2020). This discrepancy might reflect subtle variations in environmental conditions during aging or differences in initial muscle composition.

Grain-finished beef tends to produce lighter, redder meat, likely due to its higher IMF content and reduced myoglobin levels compared to pasture-finished beef (Priolo et al., 2001; Apaoblaza et al., 2020). Muscle from grass-finished cattle possesses more myoglobin, perhaps making it appear darker, and it has greater mitochondrial-based oxidative enzyme content, has fewer glycolytic enzymes, and when subjected to an in vitro glycolysis system produces less lactate (Apaoblaza et al., 2020). In addition, Apaoblaza et al. (2020) reported greater values for meat a^* and L^* coordinates from grain-finished compared to their forage-finished cattle counterparts. This difference is often attributed to variations in ultimate pH, myoglobin levels, and IMF content, which are considered key contributors (McKeith et al., 2016). However, in this study, the IMF content and ultimate pH were similar between diets, suggesting other factors, such as unmeasured myoglobin concentration, may explain these differences. The growth paths during backgrounding on pastures and the short period (100 d) of grain-fed finishing and slaughter in similar carcass weight and composition (Bruns et al., 2004; Kern et al., 2014) may be explained by the lack of differences in IMF content between finishing diets. The present study indicates that the aging combination methods decreased the color parameters (a^* and b^*). Although combined aging methods decreased a^* and b^* values, the calculated ΔE values (instrumental color differences) were below thresholds detectable by untrained observers, suggesting a minimal visual impact on consumer perception (King et al., 2023). No value was higher than 2.7; it is an instrumental difference, but not evident to consumers or the naked eye. Only trained evaluators might discern these subtle differences (Mokrzycki & Tatol, 2011).

After 40 d of aging, DAb samples exhibited a slightly higher pH (5.77) than WA samples (5.73). Several studies reported an increase in pH after 21 d of dry bag aging beef and a decrease in WA between 20 d and 40 d of aging (Dikeman et al., 2013; Li et al., 2014; Obuz et al., 2014; Kim et al., 2017; Zhang et al., 2019). These authors indicated that this increase in pH after dry bag aging could be associated with the generation of nitrogenous compound products from proteolysis; meanwhile, the lower pH in wet aging would be caused by the greater accumulation of lactic acid. Also, Triki et al. (2018) reported that pH increases during meat chilled storage were associated with the production of nitrogenized basic compounds, because microbial spoilage are conditioned by the type of packaging.

In agreement with our findings, Laster et al. (2008) found greater cooking yields in traditional dry-aged (without packaging) striploin steaks than in wet-aged. On the other hand, de Faria Vilella et al. (2019) reported no significant differences in CL between the unaged and aged samples (wet, dry, and combined) during 28 d. The difference from the previous studies is the dry aging method: bag versus traditional dry aging, implying less loss and greater cooking yields in dry bag aging. The reduced CL in DAb compared to WA is attributed to differences in moisture loss through evaporation during the dry bag aging process, as previously explained (Zhang et al., 2019; Juárez et al., 2011). The intermediate values in DW and WD aging methods further support the idea that combining dry and wet aging helps balance water loss and flavor development, enhancing overall product quality.

Previous studies had indicated that beef loins assigned to stepwise dry/wet-aging had lower WBSF values (2.66 kg) compared to the loins assigned to conventional dry aging (2.94 kg) (Kim et al., 2017). However, de Faria Vilella et al. (2019) reported no differences in WBSF due to the aging methods (wet, dry, and their combination). The discrepancy between studies could be due to the handling and the way the sample was fabricated for the different preservation methods. Consistent with most experiments (Dikeman et al., 2013; Ahnström et al., 2006; Berger et al., 2018), our study showed no differences in WBSF between aging methods (DAb, WA, DW, and WD), and the values were below 3 kg, indicating that the products could be considered as moderately tender (Smith et al., 2008).

Effects of aging method and finishing system on fatty acid profile and oxidation

Previous studies reported no interaction between diet and aging treatments on the fatty acid composition of beef (Jiang et al., 2010). However, our work showed

an interaction effect on SFA, MUFA, and PUFA. No significant differences in SFA and MUFA concentrations were observed regarding the finishing diet. The higher IMF levels in DW compared to WA could be explained by the water loss during the dry aging process. However, this does not fully account for the change, as the IMF content of dry-aged bag steaks was not significantly different from that of DW steaks. Supporting this observation, Wood et al. (2008) reported that the amount of IMF influences the fatty acid composition of beef, with SFA deposition increasing as total fat rises. Interestingly, PUFA, PUFA n6, and C18:3n3 concentrations were greater in DAb, WA, and WD from pasture-finished, underlining diet's influence on oxidative stability. The PUFA n3, n6: n3 ratio and PUFA: SFA were unaffected by the interaction between AM and F; there was an increase in PUFA n3 and n6: n3 ratio in pasture-finished steers compared to grain-finished steers. The nutrient composition of animal diets influences the fatty acid profile of meat, making it more appealing to health-conscious consumers and meat flavor in grass-finished animals (Nuernberg et al., 2005; Melton et al., 1982). Regarding human health, one relevant aspect is the concentrations of the omega 6 (n6) and omega 3 (n3) fatty acid families (Daley et al., 2010). The Department of Health (1994) of the United Kingdom has published recommended intakes of fatty acids with an n6:n3 ratio of ≤4, which was reached in our study of meat from pasture-finished steers, in agreement with previous studies (Nuernberg et al., 2005; Brito et al., 2014). The greater content of CLA, PUFA, and PUFA n3 agreed with the findings reported by Realini et al. (2004), Ponnampalam et al. (2006), and Jiang et al. (2010). Regarding meat flavor, linolenic fatty acid (C18:3n3) is an important precursor (Ba et al., 2012), and its greater concentration in beef from pasture-finished animals had a negative impact on desirable beef flavor (Melton et al., 1982). However, the odor detection threshold values for the lipid-derived compounds are much higher than those for the sulfur and nitrogen-containing heterocyclic compounds formed from the water-soluble precursors via the Maillard reaction (Ba et al., 2012). Therefore, the aroma significance of many of these lipid-derived compounds is not as great as that for relatively low concentrations of the heterocyclic compounds.

In agreement with Berger et al. (2018), SFA, MUFA, and PUFA (mg/g) did not differ among AM in our study. Conversely, Kim et al. (2017) reported that SFA, MUFA, and PUFA content (mg/g) in wet-aged was greater than in dry-aged beef after 40 d aging in top round and shank (muscle from the leg). Kim et al. (2017) reported higher C18:3n3 content in wet aging than in dry aging, indicating their negative effect on flavor when reacting with volatile compounds from the cooking process. The difference between our findings could be that the dry aging in the bag allows less exposure to oxygen compared with the traditional dry aging, suggesting that the oxidative stability of fatty acids would be less affected by AM.

Lipid oxidation, a key factor affecting meat quality, occurs through the reaction of PUFA with reactive oxygen species, leading to secondary products like aldehydes (Park et al., 2006). This process is one of the major factors responsible for the sensory and nutritional quality of meats gradual reduction. In our study, the AM * F interaction affected the oxidative stability of lipids; the highest TBARS value was in WD from grain-finished steers. This could be attributed to the higher IMF content in grain-finished meat, as lipids are more prone to oxidation due to their composition and exposure to oxygen during aging (Nam & Ahn, 2003). No differences in TBARS values were observed among AM from pasture-finished steers. Zhang et al. (2020) reported no differences in TBARS between dry aging bags versus stepwise (21 d) in samples from pasture-finished cattle. In this sense, Ha et al. (2019) reported no difference in TBARS between dry and wet aging after 35 d of storage. Studies reported increasing TBARS values and off-flavor in aerobically packaged meat (Nam et al., 2001) and less oxidation (less TBARS) in steaks from loin dry-aged in a bag compared with traditional dry aging (DeGeer et al., 2009), suggesting that using aging in bags prevents oxidative deterioration (Zhang et al., 2020). Additionally, the combination aging processes (DW and WD) demonstrated intermediate oxidation levels, suggesting that they partially mitigate the oxidative effects of prolonged aging.

Pasture-finished steers demonstrated lower TBARS values, consistent with their higher vitamin E concentrations reported in previous studies (Realini et al., 2004; Nuernberg et al., 2005; Daley et al., 2010), which delays lipid oxidation and metmyoglobin formation (Schwarz et al., 1998; Zerby et al., 1999; Descalzo & Sancho, 2008). While vitamin E levels were not measured in this study, their influence is evident from the greater oxidative stability in pasture-finished samples.

Effects of aging method and finishing system on superficial microbial counts

Aging methods did not impact the ENT counts as reported by Li et al. (2013) and Ahnström et al. (2006). Enterobacteriaceae is a specific family of bacteria that

includes several pathogens and is a fecal contamination indicator whose threshold is 4 to 5 log CFU/cm^2 according to European Union microbiological regulatory criteria (Rinn et al., 2024). TBC and PSY counts had the same behavior and their highest count was observed in WD, and the lowest load values were in WA and DW. Campbell et al. (2001) reported no trend in microflora when beef was stored under vacuum after dry aging. Therefore, vacuum packaging (the first step in WD) possibly creates a microclimate with high humidity, ideal for the growth of psychrophilic bacteria (Gardner, 1981). Psychrophilic bacteria are particularly relevant for products kept under chilling conditions since these microorganisms can still multiply (González-Gutiérrez et al., 2020). Thus, meat juices are a suitable breeding substrate for microorganisms. In WD, bacteria from wet aging are not eliminated during dry aging; instead, some may survive and multiply. As a result, a higher microbial load in WD is observed compared to wet or dry bag aging alone. Previous studies have indicated that levels of 6 to 8 log CFU/g of microorganisms (PSY) are sufficient to produce off-odors and appearance defects in meat, and that these values trigger strange smells and surface sliminess in meat (Griffiths et al., 1981; Stanbridge and Davies, 1998). Moreover, off-flavor, a spoilage result in meat, can be detected when the TBC is around 7 log CFU/cm^2 or g. However, some negative changes can be observed much earlier with TBC numbers between 5 and 6 log CFU/cm^2 or g of meat product (Feiner, 2006). In our study, the highest TBC and PSY counts in WD aging reached almost the loads to produce off-flavor (4.6 and 6.5 log CFU/cm^2 TBC and PSY, respectively). However, it seems that off-flavors were not detected by consumers since meat samples were scored at least as high as "I like it" for flavor.

Regarding the finishing diets, other studies have reported insufficient differences in microbial counts between grain- and pasture-finished beef in concordance with our results (Duarte et al., 2022; Casas et al., 2021; Zhang et al., 2010). These authors stated that other aspects, such as how beef is processed, may play a more important role in microbial contamination of meat than diet. The microbial count for the 3 families studied was just below the thresholds allowed from the point of view of safety and off-flavors.

Effects of aging method and finishing system on consumer sensory panel

Consumers ($n = 100$) preferred meat from DAb or WA, while the less acceptable beef was from WD. Berger et al. (2018) reported no difference across aging treatments (wet, dry, and dry bag) in the meat sample's overall liking scores from grass-finished heifers. In addition, Ha et al. (2019) reported higher acceptability for eating attributes (tenderness, juiciness, flavor, and overall liking) in wet-then-dry-aged beef in Japanese consumers. In terms of finishing diet, consumers preferred meat from grain-finished steers for the 3 attributes evaluated. This difference might not be due to the IMF content because no differences were found in this variable associated with the animal diet. Panelists have shown that fat flavor intensity was higher in beef from concentrate-finished steers than grass-finished steers, even though fat contents were similar (Melton et al., 1982). These authors suggested that differences were because of effects of diet on the fatty acid composition of beef, especially PUFA, which elicit undesirable aroma flavors owing to their PUFA-derived products lowering or inhibiting the formation of some heterocyclic Maillard products (Ames et al., 2001). In our study, flavor differed between finishing diets and C18:3n3 was higher in beef from forage treatments compared to the grain diet treatments, but the effect was limited since all aging treatments received high acceptability (≤4 "I like it") for tenderness, flavor, and overall liking.

When the consumer data were analyzed in Clusters (Font-i-Furnols et al., 2009), the interaction AM * F was observed. In Cluster 1, i.e., "Grain-finished wet aged beef likers", the least preferred sample was from DW and pasture-finished animals for overall, tenderness, and flavor liking. Meanwhile, in Cluster 2, i.e., "Grain-finished dry aged beef likers", the least preferred beef was from WD aging and grain-finished animals. Thus, it can be hypothesized that the stepwise aging procedure (DW or WD) could produce changes in the tenderness and flavor of the beef that influence Cluster 1 and 2 consumer acceptability (decreasing it). One possible reason for this could be lipid oxidation (Figure 4), because the consumers might have detected off-flavor in stepwise AM, particularly in the WD. In addition, WD presented microbial loads close to the threshold for off-flavor developments. However further insight would be needed to fully understand the possible reason for this lower acceptability in the sensory characteristics of WD-aged beef. On the other hand, Ha et al. (2019) working with Australian consumers reported opposite results since wet-then-dry aging (21 d wet + 35 d dry) had better acceptability scores for flavor and overall liking compared to wet-aged beef. Differences between studies may be due to consumer preferences by country (Font-i-Furnols et al., 2006), type of beef (Campo et al., 1999),

production system (Priolo et al., 2001), and aging process (Brewer & Novakofski, 2008; Lepper-Blilie et al., 2016). Consumers from Clusters 1 and 2 preferred beef from grain-finished over pasture-finished steer. These results are surprising since Uruguayan consumers used to eat beef from pasture-finished animals, and the habits greatly affect preferences (Font-i-Furnols & Guerrero, 2014; Font-i-Furnols et al., 2006). Meanwhile, in Cluster 3, regardless of some differences, consumers scored all meat samples between 4 and 5 for overall and flavor liking, closer to "neither like nor dislike"; thus, they hesitated more when making their decisions.

Despite slight differences between treatments and consumer groups, aged beef was well accepted under instrumental meat quality assessment and microbiological data.

Conclusion

Aging methods most impacted physicochemical and microbial characteristics, while finishing diet affected fatty acid composition and consumer panel. Meat quality characteristics such as color (except L^* values), pH, CL, and WBSF did not present differences due to the finishing diet and its interaction with the aging method. Under the conditions of the present study, all aging methods were acceptable from the consumer's standpoint, but combining both aging techniques (wet and dry in a bag) would not represent a suitable alternative to improve the consumer's meat sensory acceptability. Either dry bag or wet aging from grain-finished steers appear valuable for the Uruguayan consumer panel. Further research is necessary to identify and develop an in-depth understanding of the safety and quality of extended aging methods in fresh beef meat.

Conflict of interest

We confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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Statement of authorship: We hereby declare that we are the sole authors of this original article and that we have not used any sources other than those identified as references. We declare that we have not submitted this original article to any other journals and that it is not under consideration for publication elsewhere.

Data availability: Data will be made available on request.

Author contributions

Daniela Correa: Methodology, Investigation, Forma analysis, Data curation, Writing–original draft, Visualization. **Marcia del Campo**: Conceptualization, Funding acquisition, Review & editing. **Santiago Luzardo**: Conceptualization, Methodology, Visualization, Writing–review & editing. **Guillermo de Souza**: Data curation. **Carlos Álvarez**: Conceptualization, Visualization, Writing–review & editing. **Maria Font-i-Furnols**: Formal analysis, Writing–review & editing. **Gustavo Brito**: Conceptualization, Methodology, Writing–review & editing, Supervision, Funding acquisition.

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Appendix A. Supplementary data

Table S1. Socio-demographic characteristics of the consumers (%).

Characteristics			All Consumers (n=100)	Cluster 1 (n=31)	Cluster 2 (n=27)	Cluster 3 (n=42)
Sex		Male	45.0	54.8	55.6	55.1
		Female	55.0	45.2	44.4	44.9
Age		< 30 years	35.0	25.8	55.6	28.6
		30-50 years	53.0	61.3	33.3	59.2
		> 50 years	12.0	12.9	11.1	12.2
Educational level		Primary school	5.0	6.5	-	7.1
		Secondary school	25.0	25.8	25.9	23.5
		University	47.0	41.9	55.6	45.2
		Post-graduate	23.0	25.8	18.5	24.1
Frequency of fresh meat consumption	Pork	Never	24.3	25.8	11.1	31.4
		Once a month	39.4	32.3	44.4	41.8
		Every two weeks	22.2	32.2	25.9	12.2
		Every week	14.1	9.7	18.5	14.6
	Beef	Never	-	-	-	-
		Once a month	3.0	3.2	3.7	2.4
		Every two weeks	9.1	3.2	7.4	14.6
		Every week	87.9	93.5	88.9	82.9
	Chicken	Never	4.1	6.5	-	5.1
		Once a month	7.2	9.7	7.4	5.1
		Every two weeks	24.7	22.6	33.3	20.5
		Every week	63.9	61.3	59.3	69.2
	Lamb	Never	15.5	19.4	7.4	17.6
		Once a month	54.6	54.8	63.0	49.0
		Every two weeks	19.6	9.7	29.6	20.5
		Every week	10.3	16.1	-	12.8

Table S2. Effects (LSM and P-values) of aging methods (AM) and finishing diet (F) on fatty acids profile (mg/100g meat).

		AM				F			AM*F
Traits	DAb	WA	DW	WD	*P-value*	Pasture	Grain	*P-value*	*P-value*
C20:3n6	11.9±0.8	11.1±0.7	11.0±0.7	11.8±0.8	*0.627*	11.0±0.6	11.8±0.7	*0.420*	*0.054*
C20:4n6	39.5±2.7	36.1±2.5	35.0±2.4	38.5±2.7	*0.483*	39.3±2.3	35.3±2.2	*0.235*	*0.150*
PUFA n3	61.2±4.3	61.5±4.3	58.1±3.6	66.5±4.7	*0.750*	89.6±5.5	41.2±2.5	*<0.001*	*0.053*
C20:5n3	10.2±0.9	10.1±0.8	9.0±0.8	10.4±0.9	*0.460*	12.5±1.1	7.9 ±0.7	*<0.001*	*0.077*
C22:5n3	18.7±1.3	17.8±1.2	17.0±1.1	18.7±1.3	*0.606*	21.2±1.3	15.4±0.9	*<0.001*	*0.096*
C22:6n3	3.3±0.2	3.1±0.2	3.1±0.2	3.4±0.2	*0.722*	3.4±0.2	3.±0.2	*0.160*	*0.109*
C16:1	31.4±2.4	31.2±2.4	46.7±3.5	45.84±3.5	*<0.001*	34.8±2.5	41.5±3.01	*0.092*	*0.616*
C24:0	4.5±0.3	4.1±0.3	3.9±0.3	3.9±0.3	*0.318*	3.7±0.2	4.6±0.3	*0.010*	*0.083*
PUFA:SFA	0.12±0.007	0.12±0.007	0.11±0.007	0.12±0.007	*0.377*	0.14±0.01	0.10±0.008	*0.006*	*0.083*

DAb: Dry aging bag; WA: Wet aging; DW: dry aging 20d + wet aging 20d; WD: wet aging 20d + dry aging bag 20d. PUFA: sum of polyunsaturated fatty acid (PUFA n6 + PUFA n3); SFA: saturated fatty acid (C10:0 + C12:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C22:0 + C24:0); PUFA n3 (C18:3n3 + C20:3n3 + C20:5n3 + C22:5n3 + C22:6n3); PUFA:SFA: Polyunsaturated/Saturated fatty acids; IMF: intramuscular fat. Different letter in the same row denotes groups statistically different ($P<0.05$) among LSMeans.

Table S3. Effects (LSM and P-values) of interaction between aging methods (AM) and finishing diet (F) on fatty acids profile (mg/100g meat).

	Pasture				Grain				Significance		
Traits	DAb	WA	DW	WD	DAb	WA	DW	WD	AM	F	AM*F
C18:2n6	146.1±12.0a	122.4±10.1b	115.7±9.5b	119.3±9.8b	105.9±8.7b	112.3±9.2b	124.9 ±10.3ab	129.3±11.0ab	*0.830*	*0.389*	*0.029*
C18_3n6	4.9±0.55a	4.8±0.54a	4.9±0.56a	4.4±0.50a	2.4±0.27b	2.6±0.28b	3.2±0.34ab	3.8±0.5a	*0.169*	*<0.001*	*0.011*
C20_2n6	3.8±0.44c	3.6±0.42c	3.0±0.35c	3.1±0.35c	5.6±0.65b	5.4±0.63b	6.8±0.83ba	7.4±0.9a	*0.829*	*<0.001*	*0.013*
C18:3n3	56.4±6.8a	50.0±6.7a	47.7±5.7a	45.9±5.5a	9.8±1.2c	13.0±1.6bc	11.5±1.4bc	15.3±1.9b	*0.611*	*<0.001*	*0.034*
C20:3n3	2.6±0.3a	2.5±0.3ab	2.1±0.2ab	2.0±0.2ab	1.9±0.2b	2.1±0.2ab	2.3±0.3ab	2.6±0.3a	*0.831*	*0.972*	*0.036*
C14:1	17.1±2.1b	15.9±2.0bc	16.9±2.1b	15.7±1.9bc	22.8±2.8b	22.6±2.9b	30.1±3.6a	33.0±4.1a	*0.067*	*<0.001*	*0.036*
C18:1n9	1748.8 ±176b	1637.2 ±176b	1644.5 ±166b	1513.0 ±152b	1707.9 ±172b	1725.6 ±174b	2174.3±219a	2387.7±247a	*0.353*	*0.057*	*0.013*
C10:0	2.1±0.2b	2.0±0.2b	1.9±0.2b	1.8±0.2b	1.7±0.2b	1.7±0.2b	2.2±0.2a	2.4±0.3a	*0.600*	*0.863*	*0.020*
C12:0	2.3±0.24b	2.2±0.22b	2.2±0.22b	2.0±0.20b	2.0±0.20b	2.0±0.20b	2.6±0.24a	2.8±0.29a	*0.306*	*0.526*	*0.015*
C15:0	17.9±2.0a	17.5±1.9a	17.5±1.9a	15.4±1.6ab	11.7±1.2b	12.3±1.3b	15.7±1.7ab	17.2±1.9a	*0.255*	*0.081*	*0.008*
C16:0	1215.9 ±121b	1151.0 ±115b	1126.1 ±112b	1034.0 ±103b	1068.0 ±106b	1082.4 ±108b	1319.7 ±132ab	1462.3 ±149.8a	*0.561*	*0.431*	*0.020*
C17:0	121.1±12.5b	109.6±12.5b	115.1±12.0b	108.4±11.2b	140.9 ±14.6b	142.0 ±14.7b	179.8±18.6a	196.0±20.8a	*0.160*	*0.001*	*0.036*
C18:0	736.4 ±78.76a	720.0 ±77.0ab	680.4 ±73.0ab	603.7 ±64.5ab	533.5 ±57.0b	556.3 ±60.0b	649.5 ±69.4ab	746.7±82.1a	*0.824*	*0.331*	*0.016*
C20:0	13.4±1.6a	13.0±1.6a	13.0±1.6a	10.9±1.3a	3.9±0.5c	4.5±0.6bc	5.2±0.6bc	5.8±0.7b	*0.635*	<.001	*0.036*
C22:0	4.8±0.6a	5.1±0.6a	4.1±0.5a	3.7±0.4ab	2.7±0.3b	3.0±0.4b	3.3±0.4b	4.1±0.5a	*0.807*	*0.007*	*0.005*

DAb: Dry aging bag; WA: Wet aging; DW: dry aging 20d + wet aging 20d; WD: wet aging 20d + dry aging bag 20d. Different letter in the same row denotes groups statistically different ($P<0.05$) among LSMeans.