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Dry aging of beef in a bag highly permeable to water vapour ☆

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Abstract

The objective of this experiment was to compare traditional dry aging of beef with a novel technique of dry aging in a highly moisture-permeable bag. Four equal-sized sections from paired beef strip loins were dry aged traditionally, unpackaged, or packaged in the experimental bag for 14 or 21 d at 3 °C. No differences ($P > 0.05$) were noted for pH, moisture, fat, total plate counts, cook loss, shear force, or any measured sensory attribute between the two aging treatments after either aging period. After 21 d, however, dry aging in the bag (versus traditional dry aging) decreased ($P < 0.05$) weight loss during aging, trim loss after aging, and yeast counts on lean tissue and increased lactic acid bacteria counts ($P < 0.05$) on adipose and lean tissue. Dry aging in a highly moisture-permeable bag is feasible, will positively impact yields and reduce microbial spoilage, and will have no negative impact on product quality.

Keywords: Beef; Dry aging; Flavour; Palatability; Sensory attributes

1. Introduction

Aging beef postmortem is associated with the development of desired palatability attributes. Aging of beef typically results in increased tenderness (Bidner, Montgomery, Bagley, & McMillian, 1985; Minks & Stringer, 1972; Warren & Kastner, 1992), flavour (Diles, Miller, & Owen, 1994; Hodges, Cahill, & Ockerman, 1974), and overall palatability (Mitchell et al., 1991; Smith, Culp, & Carpenter, 1978). There are two fundamental ways to age beef: wet and dry aging. Wet aging involves vacuum packaging meat into a highly moisture-impermeable bag and storage under refrigeration for a specified length of time. Traditional dry aging exposes unpackaged meat directly to cooler conditions with strict temperature, humidity, and air-flow control.

Although most beef is wet aged, meat processors that dry age cite flavour impact as the primary reason for dry aging. Dry aging provides accentuated, desirable flavour in some studies (Campbell, Hunt, Levis, & Chambers, 2001; Warren & Kastner, 1992), but not others (Oreskovich, McKeith, Carr, Novakofski, & Bechtel, 1988; Parrish, Boles, Rust, & Olson, 1991). Tenderness difference comparisons between dry-aged and wet-aged products have shown no difference (Minks & Stringer, 1972; Warren & Kastner, 1992) or improved tenderness by dry aging (Parrish et al., 1991). Minks and Stringer (1972), Oreskovich et al. (1988), and Parrish et al. (1991) found no effects on shear force between wet and dry-aged product. Universally, the greatest detriment to dry aging of beef is the costs associated with decreased yields and greater weight losses during aging and trimming (Oreskovich et al., 1988; Parrish et al., 1991; Warren & Kastner, 1992). Yet it remains one of the most popular forms of aging beef for upscale restaurants, due to perceptions by consumers of premium quality.

Traditional dry aging consists of placing unpackaged subprimals into a cooler with closely controlled operating

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conditions. Some operators practice an "all in" and "all out" protocol to help minimize variation in cooler parameters and maximize final quality. If aging could occur in a highly moisture-permeable bag, however, it may be possible to "dry-age" beef in a vacuum package and have it be more tolerant to more variable cooler conditions. Such methodology could potentially decrease trim loss and microbial contamination, thus maximizing yields. The objective of this research was to compare traditional, unpackaged, dry aging with dry aging in a highly moisture-permeable bag for their impact on physical, chemical, microbial, and sensory properties of steaks from beef strip loins.

2. Materials and methods

2.1. Raw material preparation

Six pairs (representing both the left and right strip loins from each of six animals) of Certified Angus Beef strip loins (IMPS #180; IMPS, 1996) were fabricated 2 d postmortem. Strip loins were selected from six carcasses weighing 340 to 390 kg, with anterior exposed surfaces that had normal bloomed beef color and were absent of quality defects. The strip loins were held at 1 °C until 11 d postmortem (simulated industry practice) and then were divided laterally so that each pair provided four 15.24-cm sections trimmed to 1.25 cm of subcutaneous fat.

One of four treatment combinations was assigned randomly to each loin section: traditional dry aging for 14 or 21 d, or novel bag dry aging for 14 or 21 d. Sections assigned to traditional dry aging were aged by direct exposure to the conditions in the dry aging cooler. Sections assigned to the novel bag dry-aging method were vacuum-packaged by using a Hollymatic Vacuum Packager (Hollymatic Corp., Countryside, IL) into bags (2.0 mil thermoplastic elastomer made of flexible polymer and rigid polyamide, water vapour transmission rate 8000 g/15 μ/m^2/24 h at 38 °C and 50% relative humidity; oxygen transmission of 2.3 mL/m^2/d at 38 °C and 50% relative humidity; TUBLIN® Smoke, Tublin Dry; ZACROS USA, Wayzata, MN). These bags had a greater than normal water vapour transmission rate to facilitate a more efficient exchange of water vapour from product surface to the atmosphere, thereby simulating dry-aging conditions.

2.2. Aging conditions

Loin sections were aged for 14 or 21 d at temperatures of 2.6 ± 0.4 °C or 2.5 ± 0.3 °C, respectively. Humidity averaged 87 ± 2.6% during the 21 d. The air was not filtered, and the air movement was limited to that of normal cooler conditions. Also, no UV lights were used. Sections were placed on wire racks, with the subcutaneous fat surface down, and sections were rotated daily among cart positions to minimize location effects. Cooler temperatures were monitored with temperature loggers (RD-TEMP-XT; Omega® Engineering, Inc., Stamford, CT).

2.3. Microbial analysis

Total aerobic, lactic acid bacteria, and yeast and mold populations were estimated by removing samples (just before weighing and trimming) before and after aging of the sections. Two 2.54-cm diameter cores approximately 2 mm thick were removed aseptically from the dorsal subcutaneous fat and ventral lean surfaces of each loin section, placed into stomacher bags (Spiral Biotech, Norwood, MA), and stomached 2 min (Seward Stomacher 400; Seward Medical, London, UK) with 0.1% peptone diluent. Appropriate dilutions were plated in duplicate and enumerated after incubation on tryptic soy agar (total plate counts, 35 °C for 48 h), Yeast and Mold Petrifilm™ (3M Microbiology Products, St. Paul, MN; 25 °C for 120 h), and Kang–Fung agar (lactic acid bacteria counts, 35 °C for 24 h).

2.4. Weight losses

Weights of loin sections were recorded before and after the assigned aging times. The percentage of weight loss during aging was calculated as: (weight loss during aging/weight before aging) × 100. Aged loin sections subsequently were trimmed to remove dry and discolored portions. The percentage of trim loss was calculated as: (weight lost due to trimming/untrimmed weight) × 100.

2.5. Steak preparation

After microbial analysis and trimming, three steaks 2.54 cm thick were removed from each section and assigned to compositional analysis, shear force, or descriptive attribute sensory evaluations. Steaks used in compositional analysis were frozen at −40 °C for later analysis. Steaks for shear force and sensory evaluations were cooked the day of steak fabrication.

2.6. pH, fat, and moisture

Samples of *longissimus lumborum* tissue only, obtained before and after aging, were frozen in liquid nitrogen and pulverized in a Waring table-top blender (Dynamics Corp. of America, New Hartford, CT). To determine pH, 10 g of pulverized sample were added to 100 mL of distilled water and mixed for 30 s, and pH values were obtained with an Accumet® glass electrode attached to an Accumet® 50 pH meter (Fisher Scientific, Fairlawn, NJ). Moisture and fat were determined on pulverized sample by using the CEM SMART (moisture) and SMART Trac (fat) systems (AOAC PVM 1:2003; Keeton et al., 2003).

2.7. Shear force

Steaks were cooked at 163 °C in a forced-air convection oven (DFG-102 CH3; G.S. Blodgett Co., Burlington, VT) on trays to an internal temperature of 71.1 °C. Internal

temperature was monitored by using copper-constantan thermocouples (Omega Engineering, Stamford, CT) inserted into the geometric center of each steak and connected to a Doric temperature recorder (VAS Engineering, San Francisco, CA). Steaks were turned once during cooking when the internal temperature was 40 °C. After cooking, steaks were over wrapped in polyvinyl chloride film and stored at 2 °C for 24 h. Six round cores (1.27 cm diameter) were obtained from each strip steak, parallel to the long axis of the muscle fibers (AMSA, 1995). Each core was sheared once, perpendicular to muscle-fiber orientation, with a Warner–Bratzler shear force apparatus (V-notch blade) connected to an Instron Universal Testing Machine (Model 4201; Instron, Corp., Canton, MA) with a 50 kg compression load cell operating at a crosshead speed of 250 mm/min. Shear-force steaks also were used to determine cooking loss as: (weight loss during cooking/raw weight) × 100.

2.8. Descriptive attribute sensory analysis

Sensory analysis was conducted at the Kansas State University Sensory Analysis Center. Panelists ($n = 6$) were highly trained, with more than 120 h of intensive training in descriptive sensory principles and methods and more than 1000 h of experience in food evaluation. In orientation sessions preceding the evaluations, panelists as a group defined and then trained to determine eight parameters, based on established references, for each sample (Table 1). Panelists evaluated each parameter without collaboration and recorded individual evaluations on a 15-point scale, where 1 had the lowest intensity and 15 had the greatest. The testing room was a round-table panel room and had lighting, temperature, humidity, and noise controls designed according to the guidelines of ASTM (1986).

Steaks were cooked at 163 °C on a countertop electric charbroiler (Model B-44; Wells Powerline, Shelbyville, IN) for 4 min, turned and cooked for an additional 4 min, and turned every 2 min until reaching an internal temperature of 68 °C. Internal steak temperature was monitored with a hypodermic probe thermocouple (RH-93607-22, Type K, Penetration; Cole-Parmer, Vernon Hills, IL) attached to a scanning thermocouple thermometer (Digi-Sense® model 92800-10; Cole-Parmer, Vernon Hills, IL). Cooked steaks were held at 20 °C for approximately 2 min and sliced into 1 × 1 × 2.5 cm pieces perpendicular to the grilled surfaces. Four of the cut pieces were placed randomly into plastic cups, kept warm by placing the cups on tiles heated to 121 °C, and presented to the panel within 5 min of cutting.

2.9. Statistical analysis

The experiment was designed as a randomized complete block with six replications. Animal served as the block and loin sections were the experimental unit. The treatment structure was a 2 × 2 factorial, with two aging methods (traditional dry aging and novel dry aging in a bag) and two aging periods (14 and 21 d). The mixed procedure SAS (2003) was used to perform type-3 tests of fixed effects for all variables. Least squares means for protected F-tests ($P < 0.05$) were separated by using least significant differences (LSD; $P < 0.05$). Denominator degrees of freedom were estimated by using the Kenward–Rogers adjustment.

Table 1
Definitions and reference values for sensory attributes[a] of beef steaks from traditional and novel dry-aged strip loins

Sensory attribute	Definition	Reference[b]
Tenderness	Ease with which sample can be cut through with molars on first bite	Beef strip steak = 7.5 Hormel Cure 81 extra lean boneless ham = 9.0
Juiciness	The amount of liquid expressed from sample at the maximum intensity from 5 to 7 chews with the molars	Hormel Cure 81 extra lean boneless ham = 5.0 Beef strip steak = 5.0
Overall aged-beef flavour	A full blended and sustained cooked beef flavour that has fewer dominating individual flavour notes, creating a smooth, balanced impression	Beef strip steak = 5.0
Beef flavour	Amount of beef flavour identity in the sample	Beef brisket = 12.0
Brown-roasted flavour	A round, full, dark caramelized aromatic generally associated with beef that has been cooked with dry heat. Measured at its highest point during initial 10 chews	Beef brisket = 12.0
Bloody/serumy flavour	An aromatic associated with blood in cooked meat products. Closely related to metallic aromatic	Beef strip steak = 5.5
Metallic flavour	The aromatics and mouthfeel of slightly oxidized metal, such as iron, copper, and silver spoons	Beef strip steak = 4.0 Dole canned pineapple juice, unsweetened = 6.0
Astringent sensation	The feeling of a puckering or a tingling sensation on the surface and/or edges of the tongue or mouth	0.05% alum. solution = 2.5 0.065% alum. solution = 3.5

[a] Sensory attributes were scored using a 15-point scale: 0 = very tough or dry, no flavour present, 15 = very tender, juicy, or intense flavour.
[b] Reference beef steak and brisket were both USDA Select grade. The steak was grilled to an internal temperature of 60 °C, and the brisket was grilled to an internal temperature of 71.1 °C.

Table 2
The pH, chemical composition, and yields of beef strip loins aged 14 or 21 d

Trait	Treatments[a]				
	Dry 14	Bag 14	Dry 21	Bag 21	SEM[b]
pH	5.5 x	5.5 x	5.7 y	5.7 y	0.09
Moisture (%)	68.2	68.0	68.0	68.1	1.08
Fat (%)	7.6	7.5	7.8	7.3	1.24
Weight loss during aging[c] (%)	6.5 x	6.3 x	10.2 z	8.8 y	0.42
Trim loss[d] (%)	15.0 x	15.3 x	17.9 y	15.6 x	1.16

[a] Dry refers to traditional dry aging and bag refers to dry aging in a highly moisture-permeable bag.
[b] Standard error of the mean.
[c] (Weight loss during aging/weight before aging) × 100.
[d] (Weight loss due to trimming/untrimmed weight) × 100.
[xyz] Least squares means in a row with a different letter differ ($P < 0.05$).

3. Results

3.1. pH, fat, and moisture

Initial loin pH values were 5.4 ± 0.1, and moisture and fat content before aging were $69.3 \pm 1.2\%$ and $6.9 \pm 1.5\%$, respectively. Dry-aging method had no effect ($P > 0.05$) on pH, fat, or moisture during either the 14- or 21-d aging periods (Table 2). Steaks from loin sections aged 21 d had slightly greater pH values ($P < 0.05$) than those aged 14 d (5.7 versus 5.5).

3.2. Weight and trim losses

No differences ($P > 0.05$) were observed between the two aging methods after 14 d for weight loss during aging or trim loss (Table 2). After 21 d, weight loss during aging increased for both aging methods ($P < 0.05$). Unpackaged loins after 21 d lost more weight during aging and trimming ($P < 0.05$) than those aged in the bags for 21 d. Loins aged traditionally for 21 d had the most ($P < 0.05$) trim loss, whereas loins aged in the bags did not differ ($P > 0.05$) between aging times.

3.3. Microbial populations

Initial total plate counts (TPC) of both adipose and lean tissue were less than 2.5 log cfu/cm^2, lactic acid bacteria counts (LAB) were less than 3.0 log cfu/cm^2, yeast counts were less than 1.5 log cfu/cm^2, and mold counts were less than 0.3 log cfu/cm^2. After aging, no differences ($P > 0.05$) were evident among treatments for TPC (Table 3). Adipose tissue from loin sections aged in the bag had more LAB than those aged traditionally ($P < 0.05$) after both aging periods. Increasing the aging period decreased ($P < 0.05$) LAB on the both tissue types, regardless of aging method. On lean tissue, yeast counts were less ($P < 0.05$) after both aging periods for loins dry aged in the bag. Yeast counts increased ($P < 0.05$) on both tissue types, for both aging methods, as length of aging increased. No differences ($P > 0.05$) were noted between aging methods after a given aging period for yeast counts on adipose tissue. Mold counts for both tissue types among all treatments remained less than 0.3 log cfu/cm^2 during aging (data not shown).

3.4. Cook loss, shear force, and descriptive sensory attributes

No differences existed among aging methods or times for cook loss, shear force, or any measured sensory attribute ($P > 0.05$) except for astringent flavour (Table 4). Although values for astringent flavour were nearly identical between aging methods, the panelists found more astringent flavour in samples aged 14 d versus 21 d ($P < 0.05$). All treatments were rated highly desirable for tenderness, aged-beef flavour, beef flavour, and brown-roasted flavour.

Table 3
Total aerobic (TPC), lactic acid bacteria (LAB), and yeast counts of adipose and lean tissue from beef strip loins aged 14 or 21 d

Trait	Tissue	Treatments[a]				
		Dry 14	Bag 14	Dry 21	Bag 21	SEM[b]
TPC (log cfu/cm^2)	Adipose	4.3	4.3	4.7	5.0	0.42
	Lean	5.1	5.1	4.3	4.2	0.46
LAB (log cfu/cm^2)	Adipose	3.3 x	6.6 z	2.4 x	4.6 y	0.60
	Lean	5.5 x	6.7 x	2.7 y	3.0 y	0.76
Yeast (log cfu/cm^2)	Adipose	2.0 y	2.4 y	3.9 x	2.8 xy	0.67
	Lean	4.2 y	2.4 x	5.2 z	4.2 y	0.45

[a] Dry refers to traditional dry aging and bag refers to dry aging in a highly moisture-permeable bag.
[b] Standard error of the mean.
[xyz] Least squares means in a row with a different letter differ ($P < 0.05$).

Table 4
Cook loss, shear force, and sensory attributes[a] of beef strip-loin steaks aged 14 or 21 d

Trait	Treatments[b]				
	Dry 14	Bag 14	Dry 21	Bag 21	SEM[c]
Cook loss[d] (%)	23.5	22.7	22.9	23.7	1.33
Shear force (N)	23.5	23.5	24.5	26.5	1.96
Tenderness	8.6	8.5	8.6	9.3	0.46
Juiciness	4.4	4.8	4.8	5.1	0.41
Aged-beef flavour	8.5	9.0	8.9	9.1	0.51
Beef flavour	9.8	9.8	9.5	9.7	0.48
Brown-roasted flavour	9.5	9.7	9.4	9.3	0.40
Bloody/serumy	3.3	4.0	3.4	3.4	0.36
Metallic	1.3	1.4	1.2	1.3	0.18
Astringent	2.1 z	2.1 z	1.4 y	1.2 y	0.16

[a] Sensory attributes were evaluated on a 15-point scale where 1 had the lowest intensity and 15 the greatest.
[b] Dry refers to traditional dry aging and bag refers to dry aging in a highly moisture-permeable bag.
[c] Standard error of the mean.
[d] (Weight loss during cooking/raw weight) × 100.
[yz] Least squares means in a row with a different letter differ ($P < 0.05$).

4. Discussion

Data indicated that all loins were of normal beef pH. Fat, moisture, and pH were not impacted by any treatment combination. The slight decrease in moisture and increase in fat during aging was expected for dry aging as the product lost moisture during aging. A lack of difference between methods in moisture and fat after aging indicates that aging method does not greatly impact composition. Oreskovich et al. (1988) determined that dry- and wet-aged subprimals yielded steaks with equal moisture and lipid contents. Parrish et al. (1991) also found dry- and wet-aged beef did not differ in pH or in proximate analysis. Neither study, however, investigated the changes in moisture and fat during aging. Changes during aging in the present study were small and suggest that steak composition was relatively static, regardless of the aging method used.

No differences in weight and trimming losses were evident for the two aging methods after 14 d. After 21 d, aging in the bags had decreased both weight and trim losses compared with traditional dry aging. Further, trim losses did not increase for the bag dry-aged treatment from 14 to 21 d. The greater yields from dry aging in a bag would have considerable positive consequences, in as much as the cost of packaging probably would be more than offset by increased yields and decreased labor costs associated with trimming.

Microbial results showed significant differences among treatments for LAB and yeast counts. On adipose tissue, the greater number of LAB on loin sections aged in the bag could be expected because this type of bacteria predominates in vacuum-packaged meat, in contrast to meat exposed to aerobic conditions (Parrish et al., 1991). Greater yeast counts on the lean tissue of traditionally dry-aged product were likely the result of direct exposure to atmospheric conditions and handling during aging. A lack of increase during aging in TPC on both tissue types and LAB on lean tissue among treatments is likely the result of surface drying during aging; yeast numbers increased during aging, however, possibly due to yeast having a lower water-activity requirement than bacteria.

In general, dry aging improves flavour (Campbell et al., 2001; Warren & Kastner, 1992) and shear force and sensory-panel scores of tenderness (Campbell et al., 2001). In this study, no differences among treatments for shear force and most sensory traits demonstrate the comparable effectiveness of the two aging methods. The similarities in shear force, flavour, and tenderness after the additional 7 d of aging are similar to Smith et al. (1978), who found that these attributes did not change after 11 d of aging. Campbell et al. (2001) found increasing dry-aging time from 14 to 21 d did not appreciably affect flavour attributes or tenderness.

The lack of differences for most quality traits studied for traditional dry aging and aging in a bag demonstrate the effectiveness of the novel dry-aging method. The advantages gained from higher yields without sacrificing sensory traits could be attractive for both large and small processors of dry-aged product. Furthermore, aging in bags would provide processors increased inventory management efficiency and more flexibility of aging in coolers that may be used for other processes.

5. Conclusions

Vacuum-packaged aging of beef typically implies ‘‘wet aging’’. With much greater than normal moisture permeability, the vacuum-packaged bags in this study may be used to dry-age beef to increase yields, limit microbial contamination, and provide business management efficiencies without affecting product quality. Given the benefits of consumer preference for this uniquely flavoured product and its greater value per pound, it is clear why many top-end processors practice dry aging. Of interest for those processors and others who may wish to dry age beef, this current research suggests that the new method of dry aging would allow it to be more economically feasible.

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