Dry-Aging Effects on Palatability of Beef Longissimus Muscle

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ABSTRACT: Beef strip loins and short loins were vacuum aged for 7 or 14 d, then these cuts were dry aged for 7, 14, or 21 d. At 2, 9, and 16 d of post-dry-aging vacuum storage, strip steaks were analyzed for sensory, physical, and microbial differences. Controls were vacuum aged for 14 d. Dry aging for 14 and 21 d produced steaks with greater ($P < 0.05$) dry-aged flavor, tenderness, and juiciness than controls or steaks dry aged for 7 d. Shear forces were lower ($P < 0.05$) for steaks dry aged for 21 d. Time of vacuum storage before and after dry aging had minimal effects on development of dry-aged flavor attributes.

Key Words: beef, dry aging, flavor, palatability, sensory

Introduction

AGING IS DEFINED AS HOLDING MEAT FOR A PERIOD OF TIME to enhance palatability (Anon. 1991). There are 2 types of aging. Vacuum or wet aging involves storing the product at refrigerated temperatures in a sealed barrier package, whereas in dry aging, the product is unpackaged and exposed to air at controlled temperature and relative humidity. Dry aging is no longer practiced widely because it results in weight losses up to 10% (Parrish and others 1991; Warren and Kastner 1992).

Numerous studies have been conducted on beef palatability over the past 40 years. Although many have found aging makes meat more tender (Minks and Stringer 1972; Parrish and others 1991; Smith and others 1979; Warren and Kastner 1992), disagreement exists about palatability aspects other than tenderness. Warren and Kastner (1992) found dry-aged products had more beefy and brown-roasted flavor than vacuum-aged or unaged products. This agrees with work by Diles and others (1994) and Hodges and others (1974), but others have found no difference or a decrease in palatability attributes, other than tenderness, of dry-aged products compared to unaged or vacuum-aged products (Davis and others 1975; Minks and Stringer 1972; Savell and others 1978). Hodges and others (1974) indicated beef flavor intensity increased in USDA Choice short loins after 15 d of dry aging, whereas USDA Standard short loins had less beef flavor intensity than controls. Beyond the scientific community, many believe in the flavor-enhancing effects of dry aging of beef (Ellis 1990). However, previous studies have focused only on times and conditions of dry aging. Virtually all fed beef is shipped in vacuum packaging; thus beef entering dry-aging operations will have been vacuum aged, and dry-aged product likely will be vacuum packaged again for distribution. Since no literature reports these combined effects, the present study examined the effects of time in vacuum before dry aging, duration of dry aging, and duration of vacuum storage after dry aging on the sensory, physical, chemical, and microbiological traits of beef longissimus muscle.

Materials and Methods

Storage Before Dry Aging

Certified Angus Beef short loins (NAMP 174, n = 18) and strip loins (NAMP 180, n = 36) were obtained from commercial processors and shipped (3 °C) to the aging facility by commercial refrigerated transport. All loins arrived at the aging facility within 7 d of packing, and temperature monitors indicated loins were never frozen. Vacuum packaging had to be intact (no leakers) for product to be selected. Vacuum-packaged short loins and strip loins were stored in vacuum at 2 °C for 7 or 14 d from packing date. After vacuum storage, the tenderloin was removed from short loins, leaving the lumbar vertebra intact and attached to the strip loin. These shell loins (short loin with tenderloin removed) and the strip loins were placed on racks for dry aging. Truck temperatures were monitored via the truck controls and verified using the trucker log sheets. Plant temperatures were monitored via the plant charts.

Dry Aging

Dry aging was conducted at 2 °C and a relative humidity of 75%. Room temperature and humidity were monitored on continuous recording charts. After dry aging for 7 or 14 d, strip loins were trimmed and vacuum packaged. Shell loins were processed into strip loins (NAMP 180) by removing the lumbar vertebra after 21 d of dry aging, then trimmed, and vacuum packaged.

All aged loins and control strip loins were shipped to the Kansas State Univ. meat laboratory in insulated shipping containers (Kol-Boy Products, Cave Spring, Ga., U.S.A.) with reusable ice packs (Kol-Boy Products). Receiving temperatures of loins ranged from 0 to 5 °C. Control strip loins (n = 18) were shipped so that they were always 14 d old when they were evaluated.

Storage After Dry Aging

Loins were stored in vacuum at 2 °C for 2, 9, or 16 d after dry aging. At each sampling time, loins were removed from the vacuum package, and 2 steaks, 2.5 cm thick, were cut,

Table 1—Definitions for sensory evaluation of dry-aged steaks

Sensory Parameter	Definition
1. Overall aged-beef flavor intensity	A full, blended and sustained, cooked beef flavor that has fewer dominating individual flavor notes. This creates a smooth, balanced impression.
2. Beef flavor intensity	Amount of beef flavor identity in the sample. Reference: Grilled beef cube steak = 12.0 (grilled until internal temp = 77 °C.)
3. Brown/roasted flavor intensity	A round, full, dark, caramelized aromatic generally associated with beef that has been cooked with dry heat. Measured at its highest point during the initial 10 chews. Reference: Grilled beef cube steak = 10.5 (grilled until internal temp = 77 °C.)
4. Bloody/serumy flavor intensity	An aromatic associated with blood in cooked meat products. Closely related to the metallic aromatic. Reference: Sara Lee sliced roast beef = 6.0
5. Metallic flavor intensity	The impression of a slightly oxidized metal such as iron, copper, and silver spoons. Reference: Dole canned pineapple juice, unsweetened = 6.0
6. Astringent sensation intensity	The dry puckering mouth feel associated with putting an alum solution in the mouth. References: 0.5% alum solution = 2.5, 0.7% alum solution = 3.5
7. Tenderness	Ease with which the sample can be cut through with molars on 1st bite. Reference: Sara Lee sliced roast beef = 10.0
8. Juiciness	The amount of liquid expressed from the sample during the 1st and 2nd chews. Reference: Sara Lee sliced roast beef = 9.0

starting at the anterior end of the strip loin. Strip loins were repackaged for storage (9 and 16 d at 2 °C) after dry aging. After cutting, the steaks were wrapped in waxed freezer paper, stored overnight, and then evaluated for sensory and physical traits.

Steak Cookery and Sensory Analysis

Steaks were cooked at 350 °C on an electric grill (**No. 8-44;** Wells Powerline, Shelbyville, Ind., U.S.A.) for 4 min, then turned, and cooked for an additional 4 min. Steaks then were turned every 2 min until they reached 63 °C (medium rare). Cooking times ranged from 11 to 15 min. Internal steak temperature was measured using a hypodermic probe thermocouple (HYP2-21-1/2-T-G-48-OST-M; Omega Engineering Inc., Stamford, Conn., U.S.A.) attached to a 450 ATT thermocouple thermometer (Omega Engineering Inc.). The grill surface temperature was measured using an infrared thermometer (Infratrace, model KM800S, Comark Ltd., Hertfordhire, England, U.K.).

Cooked steaks were held at 20 °C for approximately 2 min and trimmed so that the center portion of the loin eye (no epimysium) muscle (longissimus lumborum) was served to the sensory panel. This center portion was cut into 1 × 1 × 2.5 cm pieces perpendicular to the surfaces that had been on the grill. Four of these pieces were placed randomly into each of 6 plastic cups labeled with the 3-digit code for that steak. Samples were kept warm by placing the cups on tiles preheated to 121 °C and presented to the sensory panel within 3 min of cutting.

The descriptive sensory analysis was conducted at the Sensory Analysis Center at Kansas State Univ.. The facility had lighting, temperature, humidity, and noise controls, and the round-table panel room was designed according to the guidelines established by ASTM (1986). The panel was composed of 6 highly trained panelists employed by the Sensory Analysis Center. Each panelist had more than 120 h of intensive training in descriptive sensory principles and method and more than 1000 h of experience in food evaluation. During the orientation period (12 h over 2 wk), panelists as a group defined and then trained to determine 8 parameters (Table 1). Panelists rated each parameter on a 15-point scale with 1 as the lowest intensity and 15 as the highest. Reference standard for flavor parameters are listed in Table 1. At each panel session, 2 reference steaks, 1 dry aged for 21 d and a control that had been wet aged for 14 d, were provided to the panelists to act as anchor points. Additionally, 2 control steaks were served in random order with the aging treatments at each panel session.

Microbial Analyses

Before strips were cut into steaks, 2 circular samples (2.54 cm in dia and 2 mm in thickness), 1 each from the fat and lean surfaces, were removed aseptically for microbial testing. Both samples from each loin were placed in a sterile stomacher bag with 100 mL sterile peptone water and stomached for 1 min, diluted as necessary, and plated to determine aerobic plate counts, lactic-acid organisms, and *Pseudomonas* spp. (Vanderzant and Splittstoesser 1992).

Physical Analyses

A 2nd steak from each treatment combination was cooked using procedures described previously. Steaks were weighed before and after cooking, and the percentage of cooking loss was calculated. Length, width, and thickness (at 3 points) also were recorded before and after cooking. Prior to cooking and immediately after, tracings were made of the steaks. The area of each tracing was determined with a video image analysis system (Optimas, ver 5.2; Seattle, Wash., U.S.A.).

To provide an instrumental measurement of tenderness, 6 to 8 cores (1.27 cm in dia) were removed parallel to muscle fibers from each steak 3 h after cooking. Each core was sheared once perpendicular to the fiber direction using a Warner-Bratzler shear attachment on an Instron (Model 4201, Canton, Mass., U.S.A.) with a 25-kg load cell and a cross-head speed of 250 mm/min. Peak force and total energy were averaged for all the cores from each steak.

Statistical Analyses

The experimental design was 3 replications of a 2 × 3 (vacuum-aging x dry-aging durations) factorial with a split plot on vacuum time post-dry-aging and for sensory data a 2nd split on panelist, with independent controls. There were 3 strip loins in each cell for each replication of the experiment. Using the GLM procedure of SAS (1994), when the model showed significant ($P < 0.05$) treatment differences, mean separation procedures were carried out using the LSD option (SAS 1994).

Table 2—Means of sensory scores for flavor traits after dry aging and after vacuum storage following dry aging

Dry aging, d	Aged flavor[a]	Beef flavor[a]	Brown roasted[a]	Bloody/ Serumy[a]	Metallic[a]	Astringent[a]
0 (controls)	9.7[d]	11.4[bc]	10.4[c]	4.8[c]	4.9[bc]	3.0
7	9.7[d]	11.3[c]	10.3[c]	4.9[b]	4.9[b]	3.0
14	10.6[b]	11.5[b]	10.6[b]	4.7[c]	4.8[c]	3.0
21	10.1[c]	11.5[b]	10.5[c]	4.8[bc]	4.8[c]	3.0
LSD	0.25	0.13	0.14	0.13	0.13	0.09
Vacuum storage after dry aging, d						
0 (controls)	9.7[d]	10.4[c]	10.4[c]	4.8[c]	4.9	3.0
2	9.8[cd]	11.4[c]	10.3[c]	5.0[b]	4.9	3.0
9	10.5[b]	11.6[b]	10.6[b]	4.7[c]	4.8	3.0
16	10.0[c]	11.5[bc]	10.5[b]	4.8[c]	4.8	3.0
LSD	0.25	0.13	0.14	0.13	0.13	0.08

[a] Flavor parameters were rated on a 15-point scale with 1 as the lowest intensity and 15 as the highest.
[b-d] Means within a column with a different superscript letter are different ($P < 0.05$).

Table 3—Means of scores for tenderness, juiciness, and Instron shear force after dry aging and vacuum storage

Dry aging, d	Tenderness[a]	Juiciness[a]	Shear force (kg)
0 (control)	10.0[d]	8.3[d]	2.3[c]
7	10.2[c]	8.2[d]	2.3[c]
14	10.6[b]	8.4[c]	2.3[c]
21	10.6[b]	9.0[b]	1.9[b]
LSD	0.18	0.14	0.14
Vacuum storage after dry aging, d			
0 (controls)	10.0[d]	8.2[c]	2.3
2	10.2[c]	8.4[b]	2.3
9	10.6[b]	8.6[b]	2.1
16	10.6[b]	8.5[b]	2.0
LSD	0.18	0.14	0.14

[a] Tenderness and juiciness were rated on a 15-point scale with 1 as the lowest intensity and 15 as the highest.
[b-d] Means within a column with a different superscript letter are different ($P < 0.05$).

Results and Discussion

Vacuum Aging Before Dry Aging

Vacuum aging for 7 or 14 d produced no effects ($P > 0.05$) on dry-aged flavor parameters, tenderness, juiciness, length, width, thickness, area, weight, or changes in these parameters due to cooking (data not shown). Product stored for 7 d before dry aging had lower ($P < 0.05$) lactic-acid bacteria counts than product stored for 14 d. This was an expected result, because storage time in vacuum packaging favors the growth of these bacteria (Smulders 1987).

Dry Aging

Dry-aging time had significant effects on all sensory attributes, except for astringent (Table 2). Dry aging for 14 or 21 d increased ($P < 0.05$) dry-aged flavor compared to 7 d of dry aging and no dry aging (control), which were similar ($P > 0.05$). This agrees with Diles and others (1994), Hodges and others (1974), and Warren and Kastner (1992), who reported dry aging produced desirable flavor changes. However, Davis and others (1975), Minks and Stringer (1972), and Savell and others (1978) found no differences or a decrease in palatability attributes, other than tenderness, during vacuum aging. This may have been because of the marbling levels of the product studied. Hodges and others (1974) indicated high-quality grade product (USDA Choice) improved in flavor attributes, whereas lower quality grade product (USDA Good) did not. In the present study, strip steaks from product aged 21 d had less ($P < 0.05$) overall dry-aged flavor than steaks from product aged 14 d. However, the 21-d dry-aged product had the lumbar vertebra attached, so the lower flavor level may have been because of the reduced lean surface area exposed to air.

Beef flavor and the brown roasted aromatics followed the trend observed with overall aged flavor; steaks dry aged for 14 and 21 d generally had higher ($P < 0.05$) levels of these flavor attributes, while the controls and the steaks dry aged for 7 d had lower scores (Table 2). For flavor attributes considered negative (bloody/serumy and metallic), the 14-d dry-aged products had lower ($P < 0.05$) scores than the 7-d dry-aged steaks, and the 21-d dry-aged steaks were similar to the 14-d dry-aged steaks. Astringent flavor was not affected ($P > 0.05$) by aging treatments. In general, these results agree with those of Warren and Kastner (1992).

Tenderness was lowest ($P < 0.05$) for the control steaks (14-d vacuum aged), and dry aging for 7 and 14 d significantly increased tenderness over the controls. Dry aging for 21 d produced steaks similar ($P > 0.05$) in tenderness to steaks dry aged for 14 d. Instron shear force was lower ($P < 0.05$) for steaks dry aged for 21 d compared to other treatments (Table 3). Controls and 7- and 14-d dry-aged steaks had similar ($P > 0.05$) shear forces. The continuing improvement in tenderness with aging by either method (vacuum or dry) beyond 14 d contrasts with reports reviewed by Jeremiah (1978) who found no significant improvements in tenderness after 11 or 14 d (Culp and others 1973; Smith and others 1979).

The cobntrol and 7-d dry-aged products had the lowest ($P < 0.05$) juiciness scores; steaks dry aged for 14 d were intermediate, and steaks dry aged 21 d had the highest ($P < 0.05$) scores. Savell and others (1978) also reported improved juiciness with aging. Explanations for increased juiciness with age might be that the meat has lost water-holding capacity and thus releases more juices as the meat is chewed, or that the

Table 4—Microbial counts at dry-aging times and at vacuum-storage times after dry aging

Dry aging, days	Aerobic count (log 10)	Lactics (log 10)	Pseudomonas (log 10)
0 (control[c])	1.4[a]	1.4[b]	2.8 [b]
7	3.3 [b]	1.4 [b]	3.5[ab]
14	3.9[b]	1.5[b]	5.3[a]
21	3.3 [b]	2.0[a]	3.3[ab]
LSD	0.73	0.49	2.21
Storage after dry aging, d			
0 (control[c])	—	1.4[b]	—
2	—	0.6[c]	—
9	—	1.7[b]	—
16	—	2.4[a]	—

[a-b] Means within a column with a different superscript letter are different ($P<0.05$).
[c] Controls were vacuum packaged for 14 days.

fat has been concentrated by moisture loss during aging. More research into the physical and textural aspects of juiciness in dry-aged products is necessary for a definitive explanation of the juiciness increase. Dry aging did not affect ($P > 0.05$) cooking time or thickness, width, length, or area of steaks (data not shown).

Vacuum Storage After Dry Aging

Post-aging storage time also contributed to aged flavor (Table 2). Generally, flavor peaked for all dry-aging treatments at 9 d of post-aging storage and then decreased at d 16. Beef and brown-roasted flavors peaked at 9 d after dry aging, although they did not differ statistically from scores for steaks stored for 16 d. Bloody/serumy flavors peaked at 2 d after dry aging and then decreased ($P < 0.05$) at 9 and 16 d. Vacuum storage after dry aging did not affect ($P > 0.05$) metallic or astringent flavors.

Tenderness improved ($P < 0.05$) during post-aging storage (Table 3). Steaks stored for 9 and 16 d after dry aging were most tender; those stored for 2 d were intermediate, and the control steaks were least tender. Juiciness was not affected by post-aging storage, however, at all post-aging times, juiciness was higher ($P < 0.05$) for all dry-aged steaks than for control steaks. Storage after dry aging had no effects ($P > 0.05$) on shear force (Table 3); cooking time; and changes in length, thickness, width, and area after cooking (data not shown).

Microbial Growth

Compared to controls, all of the dry-aged steaks had higher ($P < 0.05$) aerobic plate counts (Table 4). Duration of dry aging did not affect ($P > 0.05$) aerobic counts. This lack of response to dry-aging time may have been because of growth inhibition caused by surface drying and storage temperatures low enough to retard growth. As expected, counts of anaerobic lactic-acid bacteria increased during storage of vacuum-packaged, dry-aged product (Table 4). At 2 d of storage after dry aging, the counts for all dry-aged strips were lower than those for controls. Counts of other organisms (aerobics and *Pseudomonas*) were low (< log 5) and too variable to show any trend due to storage after dry aging.

Conclusions

CLEARLY, DRY AGING FOR A MINIMUM OF 14 D INCREASED some flavor attributes in high-quality beef that are not typically associated with vacuum-aged beef. Tenderness and juiciness also improved during dry aging. The development of palatability attributes can be sufficient to offset the expense incurred due to dry aging. The mechanism that imparts the flavor changes in the presence of air and drying conditions is still not well elucidated. Vacuum storage for up to 14 d before and 16 d after dry aging did not have major affects on palatability changes imparted by dry aging. This means purveyors who want to dry age their products can still achieve the flavor changes associated with dry aging using beef that was previously vacuum packaged. Further, since vacuum packaging after dry aging does not impair the flavor attributes of dry-aged beef, the product can be repackaged after dry aging for storage, transport, and inventory control for the end user. Costs associated with dry aging have to be evaluated against the benefits of enhancing certain flavors.

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