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Effect of Feeding Regimen and Vacuum-Packaged Storage on Sensory and Physical Properties of Beef Steaks

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ABSTRACT

The longissimus, semitendinosus and semimembranosus muscles from 12 grain-fed and 12 forage-fed cattle were vacuum packaged, stored for either 7 or 21 d and retail packaged and displayed. Primal and retail cut appearance traits and sensory attributes were evaluated. Longissimus steaks had a more yellow fat color after 5 d of display ($P<0.05$) and semitendinosus had a more intense flavor ($P<0.05$) when taken from forage-fed cattle. Generally, there were only a few minor differences in sensory properties due to feeding regimen. Primal and retail cut appearance traits (primarily muscle color and percentage surface discoloration) of all three muscles were significantly affected by the length of storage; however, storage period affected sensory properties on only the longissimus and semitendinosus muscles.

In recent years, the interest in utilizing more forage and less grain in beef cattle finishing systems has increased dramatically. A substantial portion of this increase can be attributed to the fact that with the ever increasing human population, land usually used for the production of grain for cattle may be used to produce grain for human consumption.

Several studies have compared the appearance and sensory properties of meat from forage-fed cattle to that of grain-fed cattle (*8,12,16,17*). The majority of these studies conclude that lean from forage-fed cattle is darker in color and the fat has a yellowish appearance. In addition, some studies have shown beef from forage-fed cattle to be less desirable in flavor and tenderness than beef from grain-fed cattle. This study was initiated to evaluate the effect of feeding regimen (grass vs. grain) and length of storage on the appearance and sensory properties of vacuum-packaged beef.

[1]*Mention of trade names, propriety products or specific equipment does not constitute a guarantee or warranty of the product by the USDA does not imply its approval to the exclusion of other products that may also be suitable.*

MATERIALS AND METHODS

Twelve grain-fed (corn silage/corn) and 12 forage-fed (brome grass-pasture) Hereford-Angus crossbred heifers were slaughtered as they were visually evaluated to have a fat thickness of 7.6 mm. The heifers were born in the fall and placed on their respective feeding regimen in spring. Heifers assigned to the grain-fed treatment were fed for 90 d on a corn silage/corn diet in a feedlot. Heifers assigned to the forage-fed treatment were grazed on brome grass for 90 d during the months of May, June and July in the south central portion of Nebraska.

The longissimus (LD), semimembranosus (SM) and semitendinosus (ST) muscles were removed from carcass sides at 48 h postmortem. Each cut was trimmed to 1.3 cm surface fat, weighed, placed in a bag (laminated nylon/saran/polypropylene) and vacuum packaged in a heat-seal chamber system. The muscles from the right side of each carcass were stored for 7 d whereas the muscles of the left side were stored for 21 d in boxes at 2-3°C.

At the end of the assigned storage period (7 or 21 d), vacuum-packaged primal cuts were removed from packages and examined for bacterial counts by swabbing a 12.9 cm^2 muscle area of 10 primal cuts (5 from the forage-fed treatment and 5 from the grain-fed treatment) of each muscle (LD, SM and ST) with a sterile dacron swab and aluminum template. Microbial counts were obtained by the pour plate technique using sterile phosphate buffer as diluent and trypticase soy agar as plating medium. Plates were counted after 5 d at 23°C.

Following bacterial analysis, each primal cut (n = 24 of each muscle) was evaluated by a trained 3-member panel for muscle color (8 = very dark red; 1 = bleached red), odor (4 = strong off-odor; 1 = no off-odor) and surface discoloration (7 = no surface discoloration; 1 = total surface discoloration) on the day vacuum packages were opened. LD muscle samples were also evaluated for external fat color (5 = extremely white; 3 = cream; 1 = extremely yellow). The cuts were reweighed and percentage purge loss was calculated.

After primal cut (n = 24 of each muscle) evaluation, 4 retail steaks (2.5-cm thick) were cut from each muscle starting from the 13th rib on the LD muscle, the face of SM muscle and the face of ST muscle. The first steak removed was used for shear force determination. The second and third steaks were assigned for sensory panel analysis and the fourth steak was used for retail evaluation. Steaks for sensory analysis were wrapped in polyethylene freezer paper, frozen (-20°C) for 2 months before evaluation.

Shear force and taste panel analysis were determined by broiling tempered steaks (24 h at 2°C) on Farberware Open-Hearth[1] broilers to a final internal temperature of 70°C. Internal temperature was monitored by iron-constantan thermocouple wires placed in the geometric center of each steak. Steaks were weighed before (frozen) and after cooking to deter-

TABLE 1. *Probability of differences[a] for certain visual and palatability properties of longissimus muscles.*

Characteristic	Source of variation		
	Feeding regime	Storage period	Feeding regimen × Storage period
Primal cut characteristics			
Weight loss (%)	NS	***	NS
Odor	NS	***	NS
Muscle color	NS	NS	NS
Fat color	NS	NS	NS
Surface discoloration	NS	***	NS
Microbial count	NS	NS	NS
Retail cut characteristics			
Fat color - day 1	NS	NS	NS
Surface discoloration - day 1	NS	**	NS
Muscle color - day 1	NS	NS	NS
Fat color - day 5	*	NS	NS
Surface discoloration - day 5	NS	***	NS
Muscle color - day 5	NS	NS	NS
Cooking and sensory properties			
Juiciness	NS	NS	NS
Ease of fragmentation	NS	*	NS
Amount of connective tissue	NS	**	NS
Tenderness	NS	**	NS
Flavor intensity	NS	NS	NS
Cooking loss (%)	NS	NS	NS
Shear force	**	*	NS

[a]NS = $P>0.05$; * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

mine percentage cook loss. Samples were allowed to cool to room temperature for 2 h before 1.3-cm cores were removed for Warner-Bratzler shear force determinations. Six cores were taken from each steak and each core was sheared twice. A 7-member, trained sensory panel evaluated cooked steak samples for juiciness (8 = extremely juicy; 1 = extremely dry), ease of fragmentation (8 = extremely easy; 1 = extremely difficult), amount of connective tissue (8 = none; 1 = abundant), overall tenderness (8 = extremely tender; 1 = extremely tough) and beef flavor intensity (8 = extremely intense; 1 = extremely bland). Panelists were trained according to procedures described by Cross et al. (6).

Steaks used for retail evaluation were placed on styrofoam trays, overwrapped with polyvinyl chloride film (PVC) and displayed for 5 d at 1-3°C under continuous (24 h/d) fluorescent lighting (Westinghouse Econ-O-Watt bulbs) at an intensity of 1925 lux at the meat surface. The steaks were scored individually by a 3-member trained panel under display lighting at day 1 (24 h after cutting) and day 5 of retail display for muscle color (8 = very dark red; 1 = bleached red) and surface discoloration (7 = no surface discoloration; 1 = total surface discoloration). The LD muscle was also scored for fat color (5 = extremely white; 3 = cream; 1 = extremely yellow).

Data were analyzed by analysis of variance using feeding regime and storage period as main effects and their interaction.

RESULTS

Probability of differences for certain visual and palatability properties of LD muscles is presented in Table 1. Feeding regimen significantly affected only fat color (after 5 d of retail display) and shear force values. Storage period had a significant effect on weight loss (purge), odor, surface discoloration of primal and retail cuts, ease of fragmentation, amount of connective tissue, tenderness and shear force values. No significant feeding regimen × storage period interactions existed.

Probability of differences for certain visual and palatability properties of ST muscles is presented in Table 2. Feeding regimen had a significant effect on muscle color at day 1 of retail display; however, none of the other variables was affected by feeding regimen. Storage period had a significant effect on odor, muscle color of primal cut and surface discoloration of primal cuts and retail cuts at day 1 and 5 of retail display. No significant feeding regimen × storage period interactions existed.

Probability of differences for certain visual and palatability properties of ST muscles is presented in Table 3. Feeding regimen had a significant effect on flavor intensity. Storage period had a signficant effect on odor, muscle color and surface discoloration of primal cuts, surface discoloration (day 1) and muscle color (day 5) of retail cuts and juiciness, ease of fragmentation, amount of connective tissue, and tenderness and flavor intensity ratings of cooked samples. No significant feeding regimen × storage period interactions existed.

Mean values for various sensory properties as significantly affected by feeding regimen are presented in Table 4. Steaks from forage-fed beef were more yellow in fat color (LD;day 5), darker in muscle color (SM), had lower shear force values (LD), and more intense flavor ratings (ST) as compared to steaks from grain-fed cattle.

Mean values for various sensory properties as affected by the length of storage are presented in Table 5. Storage period significantly affected primal and retail cut appearance factors and the sensory properties of steaks from LD and ST muscles, whereas only the primal and retail cut ap-

TABLE 2. *Probability of differences[a] for certain visual and palatability properties of semimembranosus muscles.*

Characteristic	Source of variation		
	Feeding regime	Storage period	Feeding regimen × Storage period
Primal cut characteristics			
Weight loss (%)	NS	NS	NS
Odor	NS	***	NS
Muscle color	NS	**	NS
Surface discoloration	NS	***	NS
Microbial count	NS	NS	NS
Retail cut characteristics			
Surface discoloration - day 1	NS	**	NS
Muscle color - day 1	*	NS	NS
Surface discoloration - day 5	NS	*	NS
Muscle color - day 5	NS	NS	NS
Cooking and sensory properties			
Juiciness	NS	NS	NS
Ease of fragmentation	NS	NS	NS
Amount of connective tissue	NS	NS	NS
Tenderness	NS	NS	NS
Flavor intensity	NS	NS	NS
Cooking loss (%)	NS	NS	NS
Shear force	NS	NS	NS

[a]NS = P>0.05; * = P<0.05; ** = P<0.01; *** = P<0.001.

TABLE 3. *Probability of differences[a] for certain visual and palatability properties of semitendinosus muscles.*

Characteristic	Source of variation		
	Feeding regime	Storage period	Feeding regimen × Storage period
Primal cut characteristics			
Weight loss (%)	NS	NS	NS
Odor	NS	***	NS
Muscle color	NS	***	NS
Surface discoloration	NS	***	NS
Microbial count	NS	NS	NS
Retail cut characteristics			
Surface discoloration - day 1	NS	**	NS
Muscle color - day 1	NS	NS	NS
Surface discoloration - day 5	NS	NS	NS
Muscle color - day 5	NS	***	NS
Cooking and sensory properties			
Juiciness	NS	**	NS
Ease of fragmentation	NS	*	NS
Amount of connective tissue	NS	**	NS
Tenderness	NS	**	NS
Flavor intensity	*	**	NS
Cooking loss (%)	NS	NS	NS
Shear force	NS	NS	NS

[a]NS = P>0.05; * = P<0.05; ** = P<0.01; *** = P<0.001.

pearance factors of the SM muscle were affected by storage period. The amount of surface discoloration on SM and ST muscles (primals) increased as storage period increased from 7 to 21 d. The amount of surface discoloration on retail cuts followed no set pattern with respect to storage period. Tenderness ratings and factors contributing to tenderness (e.g., ease of fragmentation and amount of connective tissue) of LD and ST muscles generally increased as the storage period increased from 7 to 21 d.

DISCUSSION

Forage-fed beef

Production of beef on less grain and more forage seems certain considering food priorities and increasing costs of grain. Several problems have been identified with forage-fed beef which include retail appearance and sensory attributes, primarily tenderness and flavor.

It is generally believed that forage feeding of cattle will

TABLE 4. *Mean values for various sensory properties as significantly affected by feeding regimen.*

Muscle	Characteristic	Feeding regimen	
		Forage-fed	Grain-fed
Longissimus			
	Fat color - day 5[a]	2.5	3.2
	Shear force (kg)	3.3	3.9
Semimembranosus			
	Muscle color - day 1[b]	5.2	4.9
Semitendinosus			
	Flavor intensity[c]	5.5	5.1

[a]Means based on a 5-point scale (5 = extremely white; 3 = creamy white; 1 = extremely yellow).
[b]Means based on an 8-point scale (8 = very dark red; 5 = cherry red; 1 = bleached red).
[c]Means based on an 8-point scale (8 = extremely intense; 5 = slightly intense; 1 = extremely bland).

TABLE 5. *Mean values for various sensory properties as significantly affected by storage period.*

Muscle	Characteristic	Storage period (d)	
		7	21
Longissimus			
	Weight loss (%)	2.53	4.11
	Odor[a]	1.0	1.4
	Surface discoloration - primal[b]	5.4	5.7
	Surface discoloration (day 1) - retail[b]	7.0	6.9
	Surface discoloration (day 5) - retail[b]	5.9	3.0
	Ease of fragmentation[c]	6.2	6.6
	Amount of connective tissue[d]	6.0	6.5
	Tenderness[e]	6.1	6.6
	Shear force	3.8	3.3
Semimembranosus			
	Odor[a]	1.1	1.2
	Muscle color - primal[f]	5.3	5.8
	Surface discoloration - primal[b]	5.6	5.0
	Surface discoloration (day 1) - retail[b]	4.9	5.8
	Surface discoloration (day 5) - retail[b]	4.0	2.7
Semitendinosus			
	Odor[a]	1.0	1.4
	Muscle color - primal[f]	4.3	4.9
	Surface discoloration - primal[b]	6.7	5.2
	Surface discoloration (day 1) - retail[b]	5.7	6.2
	Muscle color (day 5) - retail[f]	4.5	4.0
	Juiciness[g]	4.3	5.1
	Ease of fragmentation[c]	4.8	5.2
	Amount of connective tissue[d]	4.7	5.1
	Tenderness[e]	4.8	5.2
	Flavor intensity[h]	5.0	5.6

[a]Means based on a 4-point scale (4 = strong off-odor; 1 = no off-odor).
[b]Means based on a 7-point scale (7 = no surface discoloration; 5 = 10-25% surface discoloration; 1 = total surface discoloration).
[c]Means based on an 8-point scale (8 = extremely ease; 5 = slightly easy; 1 = extremely difficult).
[d]Means based on an 8-point scale (8 = none; 5 = slight; 1 = abundant).
[e]Means based on an 8-point scale (8 = extremely tender; 5 = slightly tender; 1 = extremely tough).
[f]Means based on a 5-point scale (5 = extremely white; 3 = cream; 1 = extremely yellow).
[g]Means based on an 8-point scale (8 = extremely juicy; 5 = slightly juicy; 1 = extremely dry).
[h]Means based on an 8-point scale (8 = extremely intense; 5 = slightly intense; 1 = extremely bland).

produce meat that is less tender than that produced by grain-fed cattle. Conflicting research reports may be due to differing quality of the forage, type of cattle, season of year, background and region of the country and other factors. In this study, the forage (brome grass) was judged to be of excellent condition and may account for the somewhat favorable results obtained on color and palatability attributes. Wanderstock and Miller (*21*), Kropf et al. (*12*), and Cross and Smith (*5*) generally agreed that forage-finished beef was of questionable tenderness; however, Schupp et al. (*18*) found very few significant differences in taste, tenderness or aroma when comparing forage-finished and grain-finished beef. Malphrus et al. (*14*) also found few significant differences in sensory consumer panel responses when comparing forage-fed to forage plus grain-fed beef. Bidner (*2*) concluded that type of diet should have little influence on organoleptic traits of beef if cattle are fed to comparable weights and grades. Because forage-fed cattle generally tend to have less subcutaneous fat, "cold shortening" may cause less tender beef from forage-fed cattle.

Flavor of forage-fed beef has been found to be less desirable than that of grain-fed beef (*2,3,21*). Bowling et al. (*3*) suggested that the composition of intramuscular lipids and/or concentration of nitrogenous extracts in muscle may be responsible for the reduced desirability of flavor of forage-fed beef.

Hedrick et al. (*9*) compared the flavor volatiles of fat of forage- and grain-fed cattle and found no difference in the qualitative analysis; however, fat of forage-fed beef had more total volatiles than the fat of grain-fed beef. They (*9*) concluded that total volatiles and certain high molecular weight compounds appear to be associated with the less desirable flavor of meat of cattle fed forage (especially fescue).

In a study comparing grass-fed beef vs. grain-supplemented beef, Reagan et al. (*16*) reported that rib steaks from grain-supplemented cattle exhibited less surface discoloration, brighter muscle color and higher consumer desirability ratings in the retail case than steaks from forage-fed cattle. However, in a similar study involving forage-fed, grain-supplemented and grain-fed cattle, Reagan et al. (*17*) observed no significant differences in any of the visual appearance traits during retail display due to feeding regimens. These workers did report that these traits were affected by a feeding regimen and length of vacuum storage interaction. In general, beef from grass-fed cattle showed greater variability in visual color traits than beef from either grain-supplemented or grain-fed beef. Kropf et al. (*12*) also studied the effect of forage feeding on muscle color and concluded that beef steaks were most desirable (lightest in color) from long-fed cattle and least desirable (darkest) from grass-fed cattle. In addition, a rapid color deterioration in muscles of grass-fed cattle indicated that they were more sensitive to preslaughter stress than grain-fed cattle.

Vacuum-packaged storage period

The appearance and color of the lean and fat tissue are important criteria which must be considered in vacuum-packaged beef. Several reports have indicated that fat from forage-fed cattle tends to be more yellow than fat from grain-fed cattle (*4,10,14*). Allen (*1*) reported that vacuum-packaged aging for 21 d of forage-fed beef improved ratings for muscle color brightness and gave a slightly less yellow fat when compared to similar steak cuts obtained at 48 h postmortem. Korpf et al. (*12*) and Reagan et al. (*16*) determined that carcasses from grass-fed cattle yielded steaks of darker color after display in a retail case when compared with steaks obtained from cattle that had received supplemental grains in addition to forages. Stribling (*20*) reported that visual color ratings and overall percentage discoloration for steaks were not affected by feeding regimen but were affected by packaging treatment. He suggested that wholesale cuts remain in vacuum storage no longer than 21 d.

Reagan et al. (*16*) indicated that consumer acceptable beef can be produced from high levels of forages if the carcasses from these cattle achieve a quality grade of U.S. Good or higher, and the primal cuts are stored in vacuum less than 21 d. Davis et al. (*7*) reported Light-Good beef was generally not inferior to that from Heavy-Choice or Heavy-Good carcasses in storage-life, retail case-life or palatability traits, if subprimal cuts were stored in vacuum packages. However, Light-Good strip loins, which were blade tenderized before storage and stored in polyethylene bags, were discolored and unattractive following storage and produced steaks which had a very limited retail case-life.

Moody (*15*) concluded that limited research indicates that beef from forage-fed animals does not have the color stability needed for optimum shelf-life and is, therefore, an area of major concern for meat scientists. Shenk et al. (*19*) reported that the feeding of grass or grass plus grain increased the myoglobin content of beef beyond that in meat from animals fed only grain. This may have been due to greater activity of the grazing animals. Longwell (*13*) reported that grass-feeding had no effect upon muscle color. Jacobsen and Fenton (*11*) reported an increase in redness or hue with increased levels of nutrition. Schupp et al. (*18*) indicated that increased grain feeding produced lean with a lighter, more cherry red color as shown by Hunter color data and visual color scores. They attributed this difference partially to pH since the forage group had a higher muscle pH than grain-fed animals. Schupp et al. (*18*) also reported that the fat on steaks from forage-fed cattle had a yellow tinge as compared to the white fat of steaks from grain-fed animals.

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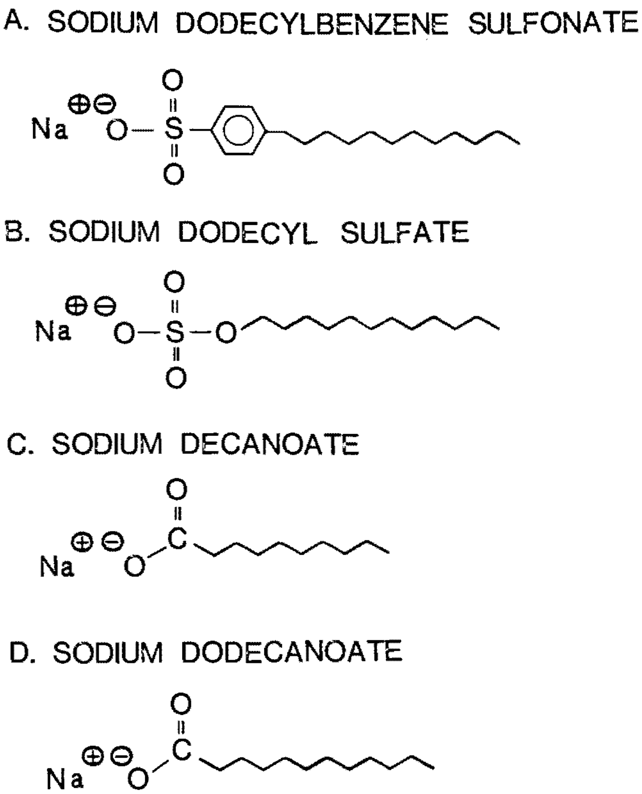

Figure 1. *Chemical structures of sodium salts of anionic detergents and soapy-flavored fatty acids.*

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