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Properties of restructured beef steaks from forage- and grain-fed cattle as affected by antioxidant and flavoring agents☆

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Abstract

Beef trimmings from cattle finished on forage or grain were restructured into steaks to enhance palatability. Steaks were treated with propyl gallate with or without a beefy flavoring agent, stored at −29 °C, and analyzed after 0, 1, 3, and 6 months. The strong grassy flavor of forage-finished beef steaks, detected by a sensory panel, was masked by the beefy flavoring agent, rendering the beef more acceptable by consumers. Propyl gallate retarded lipid oxidation and rancidity development in steaks during extended frozen storage. Microbial populations decreased while color scores, cooking yield, and binding strength of steaks exhibited only minor changes during storage. Thus, the combination of antioxidant and flavoring agents with the muscle restructuring technology provides an effective means to enhance the palatability and storage stability of beef from forage-fed cattle.

Keywords: Restructured beef; Flavor; Oxidation; Antioxidant; Frozen storage

1. Introduction

The production of beef cattle on forage or grass is of strategic importance because of the rapid growth of world's human population that foreseeably would result in a global shortage in grain supply. Today, the majority of beef cattle produced in the US are on a grain-supplemented diet or finished on grain. However, fluctuations of grain prices had long prompted the US beef cattle industry to consider alternative feeding managements aimed at reducing grain utility in the feedlot (Seideman, Cross, Bidner, Fox, Reagan, & West, 1985). The relative stability of grain production cost in recent years owing to the emerging plant biotechnology does not predict the future of the grain market. Furthermore, the increasing popularity of 'organic' food has created a new demand for beef that is produced from 'all-natural' feed materials. For example, beef produced on forage has been shown to contain more conjugated linoleic acid (CLA, a health-promoting lipid) when compared with beef from grain-supplemented cattle (Shantha, Moody, & Tabeidi, 1997). All these factors necessitate the exploration of producing beef cattle exclusively on forage. Having a natural abundance in high-quality forage and a relatively mild climate, Kentucky and the surrounding regions are particularly conditioned for beef cattle production with less grains and more roughage.

In the US, beef from grass-fed cattle is generally discriminated against because of its perceived undesirable flavor characteristics associated with odorous compounds deposited in the fat. These off-flavors have been described in terms of 'grassy', 'milky-oily', 'soured dairy', and 'fishy' (Larick & Turner, 1990; Melton, Black, Davis, & Backus, 1982; Xiong, Moody, Blanchard, Liu, & Burris, 1996). In addition, forage-finished beef contains higher concentrations of polyunsaturated fatty acids (PUFA), compared to grained-fed or supplemented beef (Srinivasan, Xiong, Blanchard, & Moody, 1998). Hence, forage-finished beef is potentially more susceptible to oxidation and may develop rancid off-flavors faster than grain-finished beef during refrigerated or frozen storage.

The objective of the study was to test the hypothesis that antioxidant and beefy flavoring treatments would reduce the objectionable flavors, particularly grassy flavor, and at the same time, minimize lipid oxidation and

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rancidity development in forage-finished beef during extended frozen storage.

2. Materials and methods

2.1. Beef samples

Eighteen yearling steers (Angus sires × crossbreed dams) weighing 257–303 kg were allotted to two forage management systems (nine cattle in each): pasture or forage only (predominantly alfalfa) (F); and forage with grain supplement (G) (Fig. 1). For the first feeding regimen (F), cattle were started on pasture in early May through mid August. The pasture arrangement for the second feeding regimen (G) was essentially the same as for the first; however, cracked corn was provided in a self-feeder while cattle were on pasture. Salt (10%) was included in with the cracked corn to restrict daily feed intake to approximately 3.7 kg/steer. When salt was completely removed, steers consumed 11.1 kg/steer/day for the last 60 days.

After being on experiment for 105 days (May–August), three randomly selected steers (replicates) from each dietary group were slaughtered at the University of Kentucky abattoir. Carcasses were electrically stimulated immediately after the dressing process (before splitting) with 500 V (2.2 A) as described by Schaake, Means, Moody, Boyle, and Aaron (1993). After 48 h postmortem aging, trimmings were obtained from the chucks, plates and briskets, and excessive fat and connective tissue (epimysium) were removed. Samples were vacuum-packaged in oxygen-impermeable double polyethylene bags (Cryovac North America, W.R. Grace & Co. Conn., Duncan, SC) and frozen in a −29 °C blast freezer where they were stored until use (<6 months).

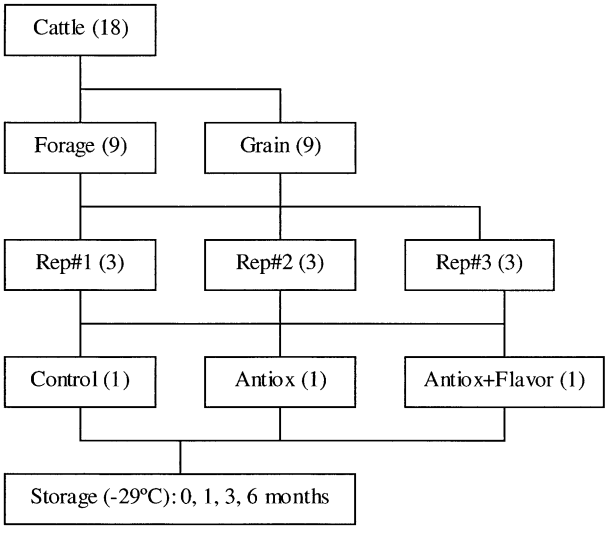

Fig. 1. A flowchart showing the experimental deign. Values in parentheses indicate number of steers.

Some beef tallow was also collected, properly labeled with animal i.d., vacuum packaged, and frozen stored as described earlier.

2.2. Preparation of restructured steaks

Packaged trimmings were thawed in a 3 °C cooler for 24 h. They were then ground through a 15.8-mm orifice plate. Fat content of ground beef from grass-fed (4.0%) and grain-fed (5.5%) cattle, determined by a modified Babcock test (Salwin, Bloch, & Mitchell, 1955), were adjusted to 10% (w/w) by adding ground fat (3.2-mm plate) from the same steers.

Restructured steaks were prepared with three formulations: (1) control, with 1.5% NaCl and 0.25% sodium tripolyphosphate (STP); (2) antioxidant, with 1.5% NaCl, 0.25% STP, and 0.015% (fat basis) propyl gallate (AO); and (3) antioxidant + beefy flavoring (AO + BF), with 1.5% NaCl, 0.25% STP, 0.015% propyl gallate, and 0.75% beefy flavoring agent (F&C Wild Flavors, Inc., Cincinnati, OH). Immediately before use, propyl gallate was pre-dissolved in 10 ml of distilled water by stirring for 2 h.

Ingredients were added separately by sprinkling on the ground meat during mixing in a Hobart upright mixer (model A-200D, Troy, OH) using the following sequential order: propyl gallate, STP, salt, then beefy flavoring. After mixing for a total of 8 min, the meat was restructured into 4-kg loaves and subsequently cut into 2.54-cm thick steaks as described by Seman, Moody, Fox, and Gay (1986). Steaks were individually wrapped with waxy butcher paper and stored at −29 °C for either 0, 1, 3, or 6 months.

2.3. Microbiological evaluation

The initial microbial loads in restructured steaks and their survival during frozen storage were examined using different procedures that detect different types of microorganisms according to FDA (1998). Specifically, four methods were utilized for enumeration and identification of microorganisms in meat samples: (1) aerobic plate count agar incubated at 26 °C for total psychrophiles; (2) aerobic plate count agar incubated at 35 °C for total mesophiles; (3) Baird–Parker agar for *Staphylococcus* bacteria; and (4) Vile Red Bile agar for total coliforms.

2.4. Colorimetric evaluation

Frozen steaks were thawed at 3 °C for 20–22 h, and objective measures of lightness ($L*$), redness ($a*$) and yellowness ($b*$) were then taken with a Hunterlab colorimeter (model D25–2; Hunter Associates Laboratories, Inc., Fairfax, VA). The instrument, with a type DZA halogen lamp light source and a 3.5-cm aperture,

was calibrated using a Hunterlab calibration plate no. C2–13717 ($L*=68.6$, $a*=23.5$, and $b*=12.8$). Before the color measurement, steaks were wrapped in a clear PVC film. Three measurements were taken on each steak at different sites and the colorimetric values were averaged.

2.5. Cooking

Thawed steaks were cooked on both sides on an open-hearth electric broiler (Farberware, Bronx, NY) to an internal temperature of 70 °C. This was done by turning the steak about every 5 min to avoid overheating on either side. A digital thermocouple (Thermolyne Digital Pyrometer, model PM 20700, Dubuque, IA) was periodically inserted into the center of the steaks to closely monitor the steak temperature during cooking. Cooked steaks were wrapped in aluminum foil and kept inside a styrofoam box with lid to maintain heat. Thus, all the samples evaluated by the sensory panel or by consumers were served uniformly warm. Steaks were weighed before and after cooking. Percent cooking yield was expressed as the weight of cooked steak divided by the weight of raw steak then multiplying by 100.

2.6. Lipid oxidation

Lipid oxidation in raw (thawed) and cooked steak samples was measured using the thiobarbituric acid (TBA) assay as described by Witte, Krause, and Bailey (1970). The assay was done within 2 h of thawing or cooking. Results were reported as mg of malonaldehyde or TBA-reactive substances (TBARS) per kg of meat.

2.7. Meat binding strength

An Instron Universal Testing Machine (model 4301, Instron Corp., Canton, MA) with a 100-kg load cell was used to determine binding strength of cooked restructured beef steaks as previously described by Xiong, Noel, and Moody (1999). Cooked steaks were allowed to equilibrate to room temperature; and with the cooked surface being removed, they were cut into 1.5-cm cubes with a sharp knife. Cubes were then placed between two parallel plates and compressed at a cross-head speed of 50 mm/min until structural failure. The breaking force was used to indicate the meat bind strength. Six samples were prepared and compressed for each treatment steak, and a total of 18 measurements per treatment were conducted (6 samples × 3 replications).

2.8. Sensory evaluation

2.8.1. Trained sensory panel

Palatability characteristics of cooked beef steaks were evaluated by an eight-member trained panel in a sensory evaluation laboratory with partitioned booths illuminated by red lights to mask color differences between samples (Xiong et al., 1999). Panelists were selected from faculty, staff, and graduate students who had previously participated in meat sensory evaluation. Prior to the actual sensory evaluation, three training sessions were conducted (AMSA, 1995). Panelists were familiarized with grassy flavor by tasting samples prepared from grass-fed cattle; a typical grass-fed beef steak would be assigned a '2' grassy flavor score, compared to a grain-finished beef with a score '0'. Furthermore, beef psoas major (tenderness score set at '10') and semitendinosus (tenderness score set at 5), both slowly grilled to 70 °C, were used as references to describe tenderness and toughness. Also, semitendinosus steaks cooked to different degrees of doneness were used to specify juiciness (score set at '8' for medium and at '2' for well-done) and tenderness, and samples with or without added beefy flavoring were used to set beefy flavor intensity, for example scores set at '8' and '5', respectively, for samples with and without 0.75% added beefy flavoring.

In the actual sensory evaluation session, all samples (ca. 1.5-cm cubes) were served in a randomized order, and evaluated for beefy flavor intensity, grassy flavor intensity, oxidative rancidity, tenderness, and juiciness. Scores were assigned on an unmarked 10-cm line anchored on the left end with the terms 'non-detectable', 'bland', or 'dry', and on the right end with the terms 'intense', 'tender', or 'juicy', depending on the sensory trait. Evaluation scores were obtained by measuring the distance of the marks assigned by the panelists from the left (0 point) or right (10 points). Between samples water was provided to rinse palates and apple juice was sipped.

2.8.2. Consumer evaluation

Restructured beef steaks were also evaluated by a consumer group recruited at the Kentucky State Fair in Louisville, KY, where steaks were cooked anew each day. A total of 108 randomly selected consumers (46% males and 54% females), ranging from 15 to 70 years-of-age, were served four cooked samples prepared and kept warmed as described earlier. The samples (ca. 1.5-cm cubes) were served (generally within 30 min after cooking) in a randomized order: (1) forage-fed beef control; (2) forage-fed beef with AO + BF; (3) grain-fed beef control; and (4) grain-fed beef with AO + BF. Consumers were asked to rate each sample for overall acceptability (0 = very low; 2.5 = low; 5.0 = medium; 7.5 = high; and 10 = very high), as well as their overall preference of each sample.

2.9. Statistical analysis

All analytical data were collected from three replicated experiments, each with duplicate or triplicate

assays, and analyzed with one-way ANOVA using the general linear model procedure of the Statistix 3.5 program (Analytical Software Inc., St. Paul, MN) for microcomputers. When a main effect (feed regimen, steak formulation, or storage time) was found significant (*F*-value), the individual means were separated by the test of least significance difference (Snedecor & Cochran, 1989). Possible interactions between main effects were not determined.

3. Results and discussion

3.1. Lipid oxidation

Control raw steaks from forage-finished steers did not show significant changes in TBARS during the first 3 months; however, TBARS increased drastically ($P < 0.05$) from month 3 (8.6 mg/kg) to month 6 (24.7 mg/kg) (Table 1). In comparison, control raw samples from steers finished on grain experienced a negligible increase ($P > 0.05$) during frozen storage. The result was consistent with previous findings that grass-fed beef was more susceptible to oxidation than grain-fed beef (Larick, Hedrick, Bailey, Williams, Hancock, Garner, & Morrow, 1987; Melton et al., 1982; Schroeder, Cramer, Bowling, & Cook, 1980; Xiong et al., 1996). Addition of propyl gallate effectively delayed TBARS production ($P < 0.05$). Cooking did not give rise to a major increase in TBARS for any of the samples.

The presence of 0.25% tripolyphosphate (added in the formulation) to the grass-fed control steaks apparently was incapable of inhibiting lipid oxidation after 3 months. Akamittath, Brekke, and Schanus (1990) reported that the prooxidant effect of salt, and other substances such as activated metmyoglobin-peroxide present in beef muscle, overcame the protective effect of the tripolyphosphate in steaks over extended storage periods. Steaks treated with propyl gallate showed minor lipid oxidation, suggesting that free radical chain reactions, rather than metal ion-dependent catalysis, might be the main mechanism involved in oxidation of restructured beef during prolonged frozen storage.

3.2. Colorimetric evaluation

The $L*$-value, averaging about 32, was not affected by the feeding regimes, or by the antioxidant and flavoring treatments or storage time (Table 2). Likewise, neither the $a*$ nor the $b*$ value differed between grass- and grain-fed cattle or affected by the antioxidant treatment. Thus, propyl gallate was ineffective in inhibiting oxidation of the heme pigment, i.e. the conversion of ferrous iron to ferric iron in the heme complex. However, both the $a*$ and the $b*$ values showed a slight decrease ($P < 0.05$) after 3 or 6 months in all samples, with the mean values changing from 21.37 (month 0) to 15.36 (month 6) for $a*$, and 8.44 (month 0) to 7.03 (month 6) for $b*$, indicating that discoloration occurred in restructured steaks.

The colorimetric results were in agreement with those reported by Schaake et al. (1993) that color attributes, including redness ($a*$), of restructured beef steaks decreased during aerobic storage. Huffman, McCafferty, Cordray, and Stanley (1984) stated that addition of salt (NaCl) to restructured beef products increased discoloration of raw steaks, and they suggested that the added salt might act as a prooxidant by interacting with the heme and reducing the pH of the meat product. An alteration of the ionic environment of the heme cleft in the myoglobin molecule may cause a destabilization of the heme structure, allowing oxidation of the heme iron

Table 1
Lipid oxidation (TBARS) of raw and cooked restructured steaks from forage-finished (F) and grain-supplemented (G) steers after frozen storage at −29 °C[a]

Sample	Month 0		Month 1		Month 3		Month 6	
	F	G	F	G	F	G	F	G
Control								
Raw	7.3bc	5.8c	5.4c	4.5c	8.6bc	9.50b	24.7ax	8.9bc
Cooked	5.1cd	4.7d	9.7bc	7.7bcd	10.3b	8.3bcd	22.4ax	8.4bcd
Antioxidant (AO)								
Raw	4.1b	3.4b	3.3b	5.2ab	5.5ab	5.0ab	8.4ay	10.9a
Cooked	4.9c	5.3b	6.6ab	4.1c	6.5ab	6.5ab	8.2ay	6.5ab
Antioxidant + beefy flavoring (AO + BF)								
Raw	4.8b	5.9ab	4.4b	4.1b	6.0ab	5.0b	8.6ay	7.7a
Cooked	5.0b	4.7b	4.6b	5.2b	5.9b	6.4ab	7.9ay	7.7a

a–d: values in the same row without a common letter differ significantly ($P < 0.05$). xy: values in the same column without a common letter differ significantly ($P < 0.05$).

[a] TBARS units are expressed as mg malonaldehyde/kg sample.

Table 2
Hunter colorimetric values of restructured steaks from forage-finished (F) and grain-supplemented (G) steers after frozen storage at −29 °C

Color parameter	Month 0		Month 1		Month 3		Month 6	
	F	G	F	G	F	G	F	G
Control								
L∗-value	33.1a	33.0a	31.6a	31.4a	32.3a	32.5a	32.8a	33.1a
a∗-value	22.1ab	21.6ab	21.4ab	23.2a	17.0c	16.5cd	14.9d	14.3d
b∗-value	8.8a	8.2a	7.3b	6.7b	7.8ab	7.2b	7.7ab	7.1b
Antioxidant (AO)								
L∗-value	33.3a	31.9ab	30.2b	30.6b	31.1a	31.5ab	32.9a	31.8ab
a∗-value	22.7a	22.6a	23.6a	23.8a	18.7b	18.2b	15.8c	16.1c
b∗-value	8.8a	8.3a	7.3b	6.7b	7.1ab	7.4b	6.6b	6.8b
Antioxidant + beefy flavoring (AO + BF)								
L∗-value	32.2a	32.0a	30.8a	31.1a	31.7a	31.9a	32.2a	32.4a
a∗-value	20.1ab	19.1b	22.1a	21.7a	17.2bc	17.0bc	15.5c	15.6c
b∗-value	8.4a	8.2a	7.0b	7.0b	7.6ab	7.8ab	6.8b	7.2b

a–d: values in the same row without a common letter differ significantly ($P < 0.05$).

to occur (Fox, 1966). As shown by Seideman, Cross, Smith, and Durland (1984), salt can also act as a prooxidant and promote pigment oxidation by reducing the oxygen tension and decreasing the buffering capacity of meat, thereby increasing the potential for myoglobin oxidation.

3.3. Microbiological stability

Because good sanitation practices were followed, the initial level of contamination (total plate counts) was relatively low (4.5 and 4.0 $\log_{10}$ cfu/g for psychrophiles and mesophiles, respectively) for all fresh steaks (results not presented). The population decreased progressively ($P < 0.01$) during subsequent frozen storage for all ingredient treatments and feed types (to 3.8 and 3.4 $\log_{10}$ Cfu/g for psychrophiles and mesophiles, respectively, after 6 months). The initial *Staphlococcus* population, 2.5 $\log_{10}$ Cfu/g, also decreased during frozen storage. In particular, *S. aureus*, tentatively identified by counting the number of clear zones in the Baired Parker plate, was quite susceptible to the freezing temperature, and was completely destroyed after 3 months. Thus, the low freezing temperature over time provided an effective means to curtail and destroy some of the microorganisms present in fresh samples. Coliforms were not detected in any of the restructured meat samples. Overall, there were no differences between grass-fed and grain-supplemented beef samples ($P > 0.05$), or between formulation treatments ($P > 0.05$), with respect to microbial survival.

3.4. Cooking yield

Steaks treated with AO + BF were higher ($P < 0.05$) than control and AO samples in average cooking yields (Table 3). It was possible that the yeast extract (making up ~55% of the beefy flavoring agent) might have contributed to water-binding in cooked steaks. Furthermore, most grain-fed beef steaks had a higher ($P < 0.05$) cooking yield than grass-fed beef. This was not expected because steaks from both dietary groups were adjusted to an equal 10% fat and formulated with the same ingredients (salt, polyphosphate, antioxidant, etc.). It is plausible that the exogenous fat added (as frozen ground pellets) to beef from grass-fed cattle was not stabilized in the same manner as the natural intramuscular fat that was present in higher amounts in restructured beef from grain-finished cattle.

3.5. Meat binding strength

Except for a few small variations, there were generally no differences ($P > 0.05$) between dietary or formulation treatments or between samples stored for different times with respect to Instron breaking force (results not presented), suggesting that restructured steaks were essentially all well bound. The result seemed to indicate that the protein exudates extracted during mixing of fresh raw meat with salt and phosphate were not denatured during frozen storage; otherwise, a cohesive bind (gel) would not have formed. This agreed with the observations by Schwartz and Mandigo (1976) and Coon, Calkins, and Mandigo (1983) who showed that restructuring eliminated variation of the low quality beef cuts and created a uniform value-added product.

3.6. Sensory evaluation by a trained panel

Beefy flavor intensity was not affected ($P > 0.05$) by dietary regimes or by storage (Table 4). However, control steaks (no antioxidant) did receive a lower beefy

Table 3
Cooking yield of restructured steaks from forage-finished (F) and grain-supplemented (G) steers after frozen storage at −29 °C

Treatment	Month 0		Month 1		Month 3		Month 6	
	F	G	F	G	F	G	F	G
Control	76.1dz	82.3abcy	82.8abcy	84.6aby	77.0cdz	83.5abx	79.2bcdy	86.3ax
Antioxidant (AO)	83.8ay	83.4ay	82.4aby	83.2ay	79.5bcy	84.5ax	76.0dz	84.3ax
Antioxidant + beefy flavoring (AO + BF)	87.2ax	86.4ax	86.4ax	87.9ax	83.0ax	84.6ax	84.2ax	86.3ax

a–d: values in the same row without a common letter differ significantly ($P < 0.05$). xyz: values in the same column without a common letter differ significantly ($P < 0.05$).

Table 4
Sensory panel scores on restructured steaks from forage-finished (F) and grain-supplemented (G) steers after frozen storage at −29 °C

Sensory trait	Month 0		Month 1		Month 3		Month 6	
	F	G	F	G	F	G	F	G
Control								
Beefy	5.29ay	5.32ay	5.33ay	5.06ay	4.83ay	4.72ay	5.01ay	4.77ay
Grassy	1.93ax	0.28ef	1.05bcdx	0.14fx	0.97cdy	1.46abcxA	1.50abcxA	1.84abx
Rancidity	**	0.08d	0.13d	0.09d	2.29cx	2.57bcx	3.91ax	3.67abx
Tenderness	6.38a	6.63a	5.80by	5.98abyB	5.24cy	6.27axy	5.77by	5.93ab
Juiciness	6.33ab	6.70a	5.98bxy	6.05aby	5.68cy	6.11aby	5.72cy	6.11aby
Antioxidant (AO)								
Beefy	5.40ay	5.94ay	5.38ay	5.52ay	5.52ay	5.21ay	5.62ay	5.50ay
Grassy	1.68ax	0.62de	1.10bcx	0.29ex	1.07bcxy	1.07bcx	1.44ax	1.32abx
Rancidity	**	**	0.12d	0.12d	1.14bcy	1.14bcy	3.00ax	3.34ax
Tenderness	6.73a	6.86a	5.80by	5.92aby	6.00abxy	6.00aby	5.82by	6.44a
Juiciness	6.68a	6.58ab	5.76cy	6.06by	6.36abxy	6.36aby	6.19aby	6.37aby
Antioxidant + beefy flavoring (AO + BF)								
Beefy	7.95abx	7.60abx	7.26bx	8.74ax	7.79abx	8.24abx	8.16abx	8.26abx
Grassy	0.48aby	0.06d	0.57ay	0.00ey	0.22bcy	0.11bcy	0.59ay	0.44aby
Rancidity	**	**	0.14c	**	0.60bz	0.11cz	1.06ay	0.89aby
Tenderness	6.38a	6.67a	6.52ax	6.60ax	6.61ax	6.61ax	6.52ax	6.32a
Juiciness	6.33b	6.77ab	6.60abx	6.92ax	7.00ax	7.00ax	6.77abx	7.02ax

a–g: mean scores in the same row without a common letter differ significantly ($P < 0.05$). xyz: mean scores for the same sensory trait in the same column without a common letter differ significantly ($P < 0.05$).
** Nondetectable.

flavor score, albeit nonsignificant, as the storage progressed, ostensibly due to the development of rancidity. As expected, the presence of beefy flavoring significantly intensified beefy flavor of restructured steaks. The AO + BF steaks received an average score of 8.00, significantly higher ($P < 0.05$) than the scores received by either AO-treated (5.49) or control steaks (5.04).

It is generally accepted that palatability of beef from cattle fed predominantly forage-based diets is different from beef from cattle fed predominantly grain-based diets. Beef from cattle raised exclusively on forage develops intense milky-oily, sour, and fishy off-flavors (Larick & Turner, 1990; Melton et al., 1982). In our study, we used the term 'grassy' to describe the off-flavor associated with grass-fed beef. Grass-fed beef had a distinctly stronger ($P < 0.05$) off-flavor compared with grain-finished beef, which was consistent with findings of Bowling, Smith, Carpenter, Dutson, and Oliver (1977), Brown, Melton, Riemann, and Backus (1979), Schroeder et al. (1980), and Xiong et al. (1996). Treatment of grass-fed beef with AO + BF lessened the grassy flavor as evidenced by the notable reduction ($P < 0.05$) in the off-flavor noted from control steaks. Steaks treated with AO-only did not differ ($P > 0.05$) from control samples, indicating that the beefy flavoring agent incorporated into restructured steaks was critical to masking the undesirable grassy flavor.

Storage increased rancidity, notably beyond 3 months ($P < 0.05$), for both grass- and grain-fed steaks, with no overall difference ($P > 0.05$) being detected between the two dietary treatments (Table 3). The latter finding seemed to be inconsistent with lipid oxidation analysis (Table 1) that clearly demonstrated a substantially larger amount of TBARS formed in control grass-fed beef than in grain-supplemented beef after 6 months. The addition of propyl gallate was ineffective in preventing the rancidity development when compared with control steak samples. However, rancidity in AO + BF samples

was less ($P < 0.05$) detectable compared to control or AO-treated steaks after 3 months, presumably due to the masking effect by the strong beefy flavoring, giving rise to a higher detection threshold.

Restructured steaks received inconsistent tenderness scores for all the formulation treatments (Table 3). However, between the formulation treatments, AO + BF steaks after 1 month storage were considered more tender ($P < 0.05$) than control and AO counterparts. Similarly, juiciness score for AO + BF steaks stored for more than 1 month was higher ($P < 0.05$) than control and AO steaks (Table 3). The difference associated with the use of the beefy flavoring can be explained because AO + BF samples had a less cooking loss than control or AO-alone samples. The 0.1% salt and 0.4% yeast extract contained in the flavoring agent probably also contributed to water-binding and hence, a higher juiciness score. The existence of an apparent relationship between meat tenderness and juiciness was not surprising, because the two sensory attributes in meat products are usually associated with each other. Despite some variations, grass- and grain-fed steaks were mostly nondistinguishable in tenderness. Also, grain-fed beef steaks were considered similar ($P > 0.05$) to grass-fed steaks in juiciness, irrespective of antioxidant or flavor treatments, although the numeric scores seem to indicate the former consistently having a higher value. Therefore, dietary regimes did not appear to affect the texture-related palatability traits.

3.7. Consumer evaluation

Consumers regarded all the four types of steaks to be acceptable (average score 6.5 out of 10), and no difference ($P > 0.05$) was found between males and females (Fig. 2). However, the acceptance score was slightly higher ($P < 0.05$) for AO + BF samples than for controls. Furthermore, it was distinctly evident that both genders preferred AO + BF samples over control samples. In fact, consumers were almost equally divided between AO + BF treated grass-fed steaks and grain-finished steaks, again, suggesting that the combination of antioxidant and beefy flavoring produced an overwhelming desirable product flavor characteristic, which was in good agreement with the trained panel result.

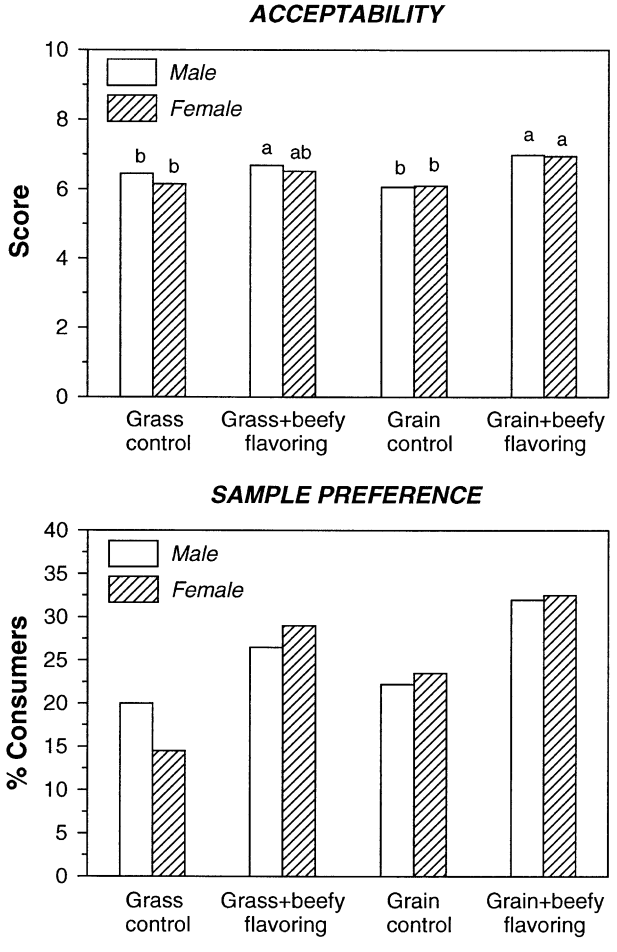

Fig. 2. Consumer evaluation and gender disparity on restructured beef steaks. Acceptability scores without a common letter differ significantly ($P < 0.05$).

4. Conclusion

Meat restructuring process that incorporates a meat flavor-enhancing agent offers a useful means to improve the palatability and consumer acceptance of beef from cattle raised exclusively on forage. This processing technology seems to be particularly suited for converting beef trimmings from grass-fed cattle into value-added products. With the addition of a proper antioxidant, the restructured beef steaks have a reduced lipid oxidation and less tendency to develop rancidity during frozen storage. Additional research is needed to establish a more effective antioxidant treatment, for example a combination of several different antioxidants, to completely inhibit the occurrence of rancidity in restructured beef steaks during extended frozen storage.

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