Effects of Forage vs Grain Feeding on Carcass Characteristics, Fatty Acid Composition, and Beef Quality in Limousin-Cross Steers When Time on Feed Is Controlled[1]

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ABSTRACT: Limousin-cross steers (n = 135; 258 ± 26 kg) were used to compare forage vs grain feeding on carcass composition and palatability attributes of beef when time on feed was controlled. Diets included a 95% alfalfa silage ration (AS) or a 68% high-moisture corn, 25% alfalfa silage ration (HMC). These were incorporated into six treatments to allow comparisons of end points based on similar days on feed or backfat finish. Dietary treatments included 1) HMC (4 mm), or cattle allowed ad libitum intake of HMC until slaughter at 4 mm ultrasound backfat; 2) AS (HMC-4), or cattle allowed ad libitum intake of AS until slaughter, regardless of finish, when HMC (4 mm) cattle were slaughtered; 3) AS (4 mm), or cattle allowed ad libitum intake of AS until slaughter at 4 mm backfat; 4) HMC (AS-4), or cattle allowed ad libitum intake of HMC until slaughter, regardless of finish, when AS (4 mm) cattle achieved 4 mm backfat; 5) HMC (RES), or cattle fed HMC at restricted intakes until slaughter at 4 mm backfat with feed offered at 75% of intake achieved by HMC (4 mm) and HMC (AS-4) cattle; and 6) AS (8 mm) or cattle allowed ad libitum intake of AS ration until slaughter at 8 mm backfat. Grain feeding generally increased ($P < .01$) ADG, carcass weight, grade fat, and intramuscular fat content when compared with forage feeding at similar times on feed. Palatability attributes of ribeye roasts and ground beef were generally unaffected ($P > .10$) by diet with the exception of slightly less beef flavor and more off-flavor in forage-fed vs grain-fed beef. Higher ($P < .01$) concentrations of linolenic acid and lower ($P < .10$) concentrations of oleic acid in forage-fed beef may be partially responsible for diet differences in flavor.

Key Words: Beef Cattle, Alfalfa, Grain, Palatability, Shear, Fatty Acids

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Introduction

Forage finishing of beef has produced mixed results on carcass characteristics and palatability attributes. Smith (1990) discouraged forage finishing because of deleterious effects on carcass and beef quality, but others (Bidner et al., 1981, 1985, 1986; Crouse et al., 1984; Fortin et al., 1985) found no differences in palatability attributes between forage- and grain-finished beef. Previously, Mandell et al. (1997) noted that many studies that compared forage vs grain finishing have been confounded regarding backfat finish and days on feed between forage- and grain-fed beef. In those studies, forage-fed cattle often had minimal amounts of finish or were slaughtered at ages older than those of grain-fed cattle. Our past work compared forage vs grain finishing at similar backfat finishes (Mandell et al., 1997). However, the experimental design allowed significant differences between dietary treatments for days fed to finish, and, accordingly, forage-fed cattle required two additional months of feeding to reach targeted slaughter end points achieved by grain-fed cattle. “Tenderness” attributes were not affected by forage finishing, but the intensity of beef flavor was greater in grain-fed beef, which was probably due in part to the effects of forage finishing on altering the fatty acid composition of beef.

Days on feed can be controlled so that diet differences in carcass composition and palatability attributes can be compared at similar times on feed for cattle fed either forage or high-grain diets. By incorporating different levels of finish for grain- and

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Table 1. Ingredients and chemical composition of diets fed to steers

	Diet, % of DM	
Composition	Alfalfa silage (AS)	High moisture corn (HMC)
Ingredient		
Alfalfa silage	94.9	15.0
High-moisture corn	0	76.5
Corn gluten/blood meal	2.5	0
Soybean meal	0	5.0
Limestone	0	1.0
Dicalcium phosphate	.1	0
Vitamin premix	2.0	2.0
Trace mineralized salt	.5	.5
Chemical		
CP	23.7	14.3
Ca	1.2	.7
P	.4	.4

forage-fed cattle, finish effects as influenced by diet can also be examined. The purpose of this study was to examine the effects of forage vs grain finishing on carcass characteristics, fatty acid composition, and palatability attributes when time on feed is controlled.

Materials and Methods

Limousin-cross steers (n = 135) from Ontario were purchased at local sales for the present study. Weaned Limousin-sired calves (approximately 6 mo in age) were used in the trial. Steers were classified on the basis of 0, 25, or 50% British breeding by three experienced cattle evaluators. The calves arrived in October and were used in a feedlot reception trial for approximately 2 mo before being allocated to one of two diets (Table 1) composed of 95% alfalfa silage (**AS**) or 77% high-moisture corn, 15% alfalfa silage (**HMC**). These diets were incorporated into six dietary treatments (Table 2) based on backfat finish or days on feed. Dietary treatments included 1) HMC (4 mm), or cattle allowed ad libitum intake of HMC until slaughter at 4 mm ultrasound backfat; 2) AS (HMC-4), or cattle allowed ad libitum intake of AS until slaughter, regardless of finish, when HMC (4 mm) cattle were slaughtered; 3) AS (4 mm), or cattle allowed ad libitum intake of AS until slaughter at 4 mm backfat; 4) HMC (AS-4), or cattle allowed ad libitum intake of HMC until slaughter, regardless of finish, when AS (4 mm) cattle achieved 4 mm backfat; 5) HMC (RES), or cattle fed HMC at restricted intakes until slaughter at 4 mm backfat with feed offered at 75% of intake achieved by HMC (4 mm) and HMC (AS-4) cattle; and 6) AS (8 mm), or cattle allowed ad libitum intake of AS ration until slaughter at 8 mm backfat. At least 21 steers were allocated to each dietary treatment with equal numbers of calves (7) with 0, 25, and 50% British breeding. All cattle were implanted with Synovex-S at the start of the trial, and cattle that were remaining at 112 d were reimplanted. Diets were formulated to satisfy NRC (1984) requirements for calcium, phosphorus, trace-mineralized salt, and vitamins A, D, and E.

Cattle were gradually adjusted to experimental diets according to the protocol described by Mandell et al. (1997). Cattle were fed their assigned diets once daily. Steers were group-fed in 2.44- × 3.05-m slatted-floor pens enclosed in a cold environment barn. Amounts of feed offered were recorded with refused feed weighed back once per week. Cattle were weighed in the morning before being fed at the start of the trial and at 28-d intervals until slaughter to calculate ADG. Shrunk weights were recorded at the start and end of the trial from cattle that had not been fed for 48 h or

Table 2. Description of dietary treatments and contrast coefficients to compare forage and grain feeding on ADG, carcass characteristics, chemical composition, and palatability attributes of beef

	Contrast coefficient[a]					
Contrast	HMC (4 mm)	AS (HMC-4)	AS (4 mm)	HMC (AS-4)	HMC (RES)	AS (8 mm)
1	1	−1	0	0	0	0
2	1	0	−.5	0	−.5	0
3	0	0	0	1	0	−1
4	0	0	1	0	−1	0
5	0	0	1	−1	0	0

[a]HMC (4 mm) = cattle given ad libitum intake of high-moisture corn (HMC) until slaughter at 4 mm ultrasound backfat; AS (HMC-4) = cattle given ad libitum intake of alfalfa silage (AS) until slaughter, regardless of finish, when HMC (4 mm) achieved 4 mm backfat; AS (4 mm) = cattle given ad libitum intake of AS until slaughter at 4 mm backfat; HMC (AS-4) = cattle given ad libitum intake of HMC until slaughter, regardless of finish, when AS (4 mm) cattle achieved 4 mm backfat; HMC (RES) = cattle fed HMC at restricted intakes until slaughter at 4 mm backfat with feed offered at 75% of intake in HMC (4 mm) and HMC (AS-4) cattle; AS (8 mm) = cattle given ad libitum intake of AS until slaughter at 8 mm backfat finish.

watered for 12 h. Ultrasound determination of backfat was conducted every 28 d using the Tokyo-Keiki LS-1000, a real-time ultrasound instrument equipped with a 3.5-MHz transducer with a 102-mm field of view. Images were printed on thermal paper and deposition of backfat (mm) measured manually. Ultrasound determinations of backfat were conducted every 14 d as soon as cattle were within 1 mm of their designated end point.

All cattle were humanely slaughtered at the University of Guelph abattoir, where electrical stimulation is not used. Hot carcass weights were recorded before overnight chilling at 1°C. Postmortem temperature and pH decline in the longissimus muscle (**LM**) were measured at 1, 3, 5, and 24 h using a spear-tipped electrode and thermocouple connected to a Fisher pH meter. Carcasses were graded in the normal manner by Agriculture Canada meat graders using the criteria effective April 5, 1992, (Agriculture Canada, 1992) for determining carcass grade.

The interface between the 12th and 13th ribs was used to obtain the following carcass measurements:

1. subcutaneous fat (mm) at ¼, ½, and ¾ positions over the LM (beginning from medial side);
2. grade fat (mm) or minimum fat in the last quadrant over the LM (from the ¾ position to the end of the lateral side for LM);
3. longissimus muscle area (**LMA**) (cm^2);
4. subjective score for color of the lean using a 5-point scale (1 = very dark red, 2 = moderately dark red, 3 = slightly dark red, 4 = cherry red, and 5 = very light cherry red);
5. subjective score for fat color using a 5-point scale (1 = lemon yellow, 2 = yellow, 3 = pale yellow, 4 = slightly tinged or off-white, and 5 = white); and
6. subjective score for marbling using a 10-point scale (1 = devoid, 2 = practically devoid, 3 = traces, 4 = slight, 5 = small, 6 = modest, 7 = moderate, 8 = slightly abundant, 9 = moderately abundant, and 10 = abundant marbling).

The 10th to 12th rib section from the left side of each carcass was removed and separated into muscle; bone; and subcutaneous, intermuscular, and body cavity fat (Lunt et al., 1985). The 13th rib was also removed from the left side of the carcass and the longissimus muscle saved for chemical analyses. Percentage yields of lean, fat, and bone were calculated by dividing separated lean, fat, or bone in the 10th to 12th rib by weight of the 10th to 12th rib and then multiplying by 100. Similarly, fat depot percentages are presented for subcutaneous, intermuscular, and body cavity.

Longissimus muscle roasts were prepared after dissection of the three-rib section, and a steak was prepared from longissimus muscle from the 13th rib. Roasts and steaks were vacuum-packaged and stored at 2°C until 7 d after slaughter. After aging, the roasts and steaks were stored at –24°C.

Chemical and Sensory Analysis of Longissimus Muscle

All epimysium was removed from the longissimus muscle steak from the 13th rib after thawing. The muscle was chopped into small cubes, freeze-dried, and then ground using a commercial coffee grinder. Determination of chemical fat was conducted using method 24.005 (AOAC, 1990) for ether extraction of fat. Water content was calculated from the difference in weight after freeze drying, corrected for any residual moisture from oven drying for 8 h at 100°C. Collagen solubility was determined using the procedure of Hill (1966).

Longissimus muscle roasts from 126 steers were evaluated by an eight-member trained taste panel for palatability attributes using CSA (1991) software. Palatability attributes included the following:

1. softness: the force required to compress the sample between the molar teeth;
2. tenderness: the force to chew measured after three chews excluding the first bite as a chew;
3. initial juiciness: amount of moisture released by the sample after five chews;
4. beef flavor: the amount of full meaty flavor present after eight chews;
5. juiciness: the overall impression of moistness perceived in the mouth after 10 chews;
6. strong flavor: the amount of strong flavor present at six to seven chews; and
7. time spent chewing: the energy (force plus time) required to chew the sample completely for swallowing.

A 10-cm unstructured line scale with verbal anchors based on quantitative descriptive analysis (Stone and Sidel, 1985) was used in which the left anchor represented scoring of either very firm (softness), very tough (tenderness), very dry (initial juiciness), very weak (beef flavor), very dry (juiciness), very weak (strong flavor), and very little (time spent chewing), and the right anchor represented scoring of either very soft (softness), very tender (tenderness), very juicy (initial juiciness), very intense (beef flavor), very juicy (juiciness), very intense (strong flavor), and very chewy (time spent chewing). Palatability attributes were evaluated using a scale from 0 to 10, with 0 always representing the left anchor and 10 representing the right anchor.

Training and conduct of the taste panel, preparation of longissimus muscle roasts for cooking, and Warner-Bratzler shear measurement of cooked beef are described by Mandell et al. (1997). In addition to sensory evaluation of LM roasts, a 10-member taste panel evaluated ground beef prepared from 120 Limousin-cross steers. The ground beef was formulated to contain 25% fat, using LM lean from ribs 6 to 9 from the left side of each carcass, subcutaneous fat over the LM, and brisket fat. The added fat contained 60% subcutaneous fat and 40% brisket fat. Ground beef was frozen and stored at –24°C. A 10-member trained taste panel was used to evaluate palatability attributes of ground beef using CSA (1991) software. Palatability attributes included the following: 1) aromas: greasy, metallic, typical beef, and grassy; 2) flavors: sour, beef, salt, and liver; and 3) aftertaste: metallic and greasy. An unstructured line scale with verbal anchors based on quantitative descriptive analysis was used in which the left anchor represented scoring of either none for all attributes except beef flavor and the left anchor was very weak. The right anchor represented very intense for the specific attribute evaluated. Palatability attributes were evaluated using a scale from 0 to 10, with 10 always representing extreme intensity.

The taste panel was trained using ground beef prepared from grain- and forage-fed beef. The taste panel was conducted 4 d/wk over a 5-wk period. Six samples were evaluated on each day of the taste panel. Ground beef was prepared for cooking by tempering for approximately 36 h in a refrigerator. Two lots of 200 g were prepared from each sample of ground beef; each lot was placed in a 600-mL beaker, fitted with a vented cover glass, before cooking in a 177°C electric oven preheated for 10 min. Ground beef was cooked for 15 min, stirred with glass rods, and repositioned on the oven shelf using a prearranged plan, and then cooked for another 10 min to a temperature of 80°C. The two beakers of ground beef for each animal were combined in a warmed Pyrex bowl, placed into sample cups that were coded to identify individual animals, and covered. Each panelist received three samples at a time and six samples per sitting, in which the order of evaluating the six samples was randomized among panelists. Water and Melba toast rounds were supplied during the training and testing sessions to clear the palate between samples.

Free Fatty Acid Analysis

A modification of the Bligh and Dyer (1959) procedure was used to obtain lipid extracts of each sample and is described in Mandell et al. (1997).

Statistical Analyses

Average daily gain and carcass data were statistically analyzed using a general linear model (SAS, 1994) to determine the effects of dietary treatment. Differences among treatment means were determined by nonorthogonal contrasts (Steel and Torrie, 1980). Contrasts included 1) HMC (4 mm) vs AS (HMC-4); 2) HMC (4 mm) vs AS (4 mm) and HMC (RES); 3) HMC (AS-4) vs AS (8 mm); 4) AS (4 mm) vs HMC (RES); and 5) AS (4 mm) vs HMC (AS-4). Contrast coefficients for diet effects are presented in Table 1. Chemical composition and palatability attribute data were analyzed using multivariate analysis of variance (MANOVA) using the model and contrast coefficients as previously described. Dependent variables in the model were based on the specific palatability attribute being statistically analyzed, which included 1) days fed; soluble collagen content (%); shear force score (newtons); intramuscular fat content (%); numerical marbling score; and pH at 1, 3, 5, and 24 h after death for analysis of the three “tenderness” variables–softness, tenderness, and time spent chewing; 2) initial and overall juiciness, beef flavor, off-flavor, days fed, evaporative cooking losses, intramuscular fat content (%), and numerical marbling score for analysis of initial and overall juiciness; 3) beef flavor, strong flavor, days fed, intramuscular fat content (%), numerical marbling score, and concentrations of individual fatty acids in LM including 14:0, 16:0, 16:1, 18:0, 18:1, 18:2, and 18:3 for analysis of beef and strong flavors; and 4) aromas, flavors, and aftertaste measurements, intramuscular fat content (%) of ground beef, and concentrations of individual fatty acids in ground beef including 14:0, 16:0, 16:1, 18:0, 18:1, 18:2, and 18:3 for analysis of ground beef. Pearson correlation coefficients were determined between traits using PROC CORR (SAS, 1994).

This experiment was conducted following the animal utilization protocol approved by the University of Guelph Animal Care Committee according to the guidelines of the Canadian Council on Animal Care.

Results and Discussion

Dietary treatments were designed such that cattle in HMC (4 mm) and AS (HMC-4) would be slaughtered after minimum time on feed but with different levels of finish. Cattle in HMC (RES) were expected to finish at similar times on feed as cattle on AS (4 mm), because restricted intakes of HMC would be equivalent in available energy to unrestricted intakes of AS in cattle fed AS (4 mm). Potentially large differences in finish were expected between AS (4 mm) and HMC (AS-4) at similar times on feed. Maximum time on feed was expected with AS (8 mm) for AS cattle to achieve 8-mm finish. Days to finish included 120 for HMC (4 mm) and AS (HMC-4), 172 for HMC (RES), 209 for AS (4 mm) and HMC (AS-4), and 247 for AS (8 mm).

Weight at start of test did not differ ($P > .10$) among dietary treatments, ranging from 253 ± 5.5 to 266 ± 6.3 kg. All five contrasts for ADG were significant (Table 3), which was expected given comparison of gains from cattle fed a 77% HMC ration vs cattle fed a 95% alfalfa silage ration, and similar to previous findings (Rompala et al., 1984) that compared cattle fed a 67% high-moisture corn diet vs a 99% alfalfa silage diet. Hot carcass weights and backfat measurements differed ($P < .01$) between HMC (4 mm) and AS (HMC-4), which is to be expected given diets with drastic differences in ME content and given that AS (HMC-4) cattle were slaughtered regardless of finish when HMC (4 mm) cattle attained 4-mm backfat. Differences ($P < .06$) in hot carcass weight between HMC (4 mm) vs AS (4 mm) and HMC (RES), and diet differences in backfat between AS (4 mm) and HMC (AS-4), and between HMC (AS-4) and AS (8 mm), were due to diet differences in metabolizable energy in which rate of fat deposition was greater in the HMC ration. Crouse et al. (1985) demonstrated that low-energy diets would increase slaughter weights relative to high-energy diets when feeding to a constant composition end point.

Greater ($P = .011$) LMA in HMC (4 mm) cattle relative to AS (HMC-4) were due to diet differences in metabolizable energy and because cattle were killed after a constant time on feed. Burson et al. (1980) found LMA to be unaffected by dietary energy content at constant times on feed, but others (Crouse et al., 1984; Bidner et al., 1985; Rumsey et al., 1987) found smaller LMA in forage-fed cattle vs grain-fed cattle. The absence of significant differences for LMA with other contrasts agrees with past studies (Fortin et al., 1985; Bidner et al., 1986) in which forage finishing did not decrease LMA relative to grain finishing when times on feed differed between diets.

Lean and fat yields differed ($P < .05$) between diets, and HMC-fed cattle deposited less ($P < .05$) lean and more ($P < .01$) fat than AS-fed cattle. Greater lean yield in forage-fed beef relative to grain-fed beef has been reported previously (Bowling et al., 1978; Schroeder et al., 1980; Schaake et al., 1993) where drastic differences in backfat existed between diets. Separable muscle did not differ between forage, silage, or grain diets according to Tatum et al. (1988), but Jones (1985) found carcass lean to be similar in forage and grain diets with data adjusted to the same proportion of subcutaneous fat. Bone yield in AS-fed

Table 3. Diet effects on average daily gain and carcass traits in Limousin-cross steers fed either a 95% alfalfa silage ration or a 68% high-moisture corn ration to various degrees of backfat finish

	Diet[a]							Probability of larger F-ratio for contrasts[b]				
Item	HMC (4 mm) (1)	AS (HMC-4) (2)	AS (4 mm) (3)	HMC (AS-4) (4)	HMC (RES) (5)	AS (8 mm) (6)	SE	1	2	3	4	5
Average daily gain, kg/d	1.64	1.35	1.14	1.56	1.33	1.12		.0001	.0001	.0001	.0045	.0001
Carcass weight, kg	272.9	228.3	306.2	327.2	290.5	312.0	10.9	.0033	.0591	.3127	.3492	.1242
Backfat at ¾ position over longissimus muscle, mm	5.5	4.0	5.1	10.3	4.8	8.3	.4	.0077	.2576	.0015	.6050	.0001
Grade fat, mm	5.2	3.9	4.8	9.9	4.4	7.9	.4	.0124	.2108	.0003	.4510	.0001
Longissimus muscle area, cm^2	81.6	70.8	82.5	83.1	83.2	80.1	3.0	.0106	.7316	.4739	.8895	.8688
Lean yield, %[c]	61.4	63.5	60.7	54.8	60.1	58.1	.7	.0485	.2619	.0017	.6475	.0001
Fat yield, %	19.4	14.6	18.9	27.2	19.4	22.3	.8	.0001	.7811	.0001	.6927	.0001
Bone yield, %	18.7	21.7	20.4	17.9	20.4	19.5	.5	.0001	.0031	.0140	.8975	.0001
Subcutaneous fat, %[d]	44.5	45.4	47.4	43.8	42.9	46.3	1.1	.6516	.7482	.2174	.0450	.0549
Intermuscular fat, %	39.7	35.4	36.5	42.9	42.9	41.4	1.6	.0416	.9761	.5034	.0077	.0012
Body cavity fat, %	15.7	19.2	16.2	13.3	14.3	12.2	.9	.0005	.6442	.4010	.1743	.0123
Marbling score[e]	3.27	2.55	3.17	4.42	3.58	3.57	.20	.0083	.6492	.0019	.1727	.0001
Lean color[f]	3.86	3.71	3.76	4.00	3.79	3.96	.08	.1795	.3775	.7023	.7757	.0154
Fat color[g]	3.96	3.95	3.91	3.95	4.00	3.89	.04	.9557	.9901	.2043	.1441	.4701

[a]Diets: 1, HMC (4 mm) = grain-fed cattle slaughtered at 4 mm backfat finish; 2, AS (MHC-4) = forage-fed cattle slaughtered regardless of finish when grain-fed cattle in Diet 1 achieved 4 mm backfat; 3, AS (4 mm) = forage-fed cattle slaughtered at 4 mm backfat finish; 4, HMC (AS-4) = grain-fed cattle slaughtered regardless of finish when forage-fed cattle in Diet 3 achieved 4 mm backfat; 5, HMC (RES) = grain-fed cattle fed at 75% of ad libitum intake of other grain-fed cattle and slaughtered at 4 mm backfat; 6, AS (8 mm) = forage-fed cattle slaughtered at 8 mm backfat finish.

[b]Contrasts: Contrast 1 = diet 1 vs diet 2; Contrast 2 = diet 1 vs diets 3 + 5; Contrast 3 = diet 4 vs diet 6; Contrast 4 = diet 3 vs diet 5; Contrast 5 = diet 3 vs diet 4.

[c]Yield data (lean, fat, bone) based on percentage lean, fat, bone in the 10th to 12th rib.

[d]Percentage dissected fat component (subcutaneous, intermuscular, body cavity) in the 10th to 12th rib.

[e]Marbling score: longissimus muscle scored subjectively for marbling using a 10-point scale (1 = devoid of marbling to 10 = abundant marbling).

[f]Lean color: longissimus muscle scored subjectively for lean color using a 5-point scale (1 = very dark red to 5 = very light red).

[g]Fat color: carcass fat scored subjectively for fat color using a 5-point scale (1 = bright yellow to 5 = white).

cattle exceeded ($P < .05$) that in HMC-fed cattle when comparing HMC (4 mm) vs AS (HMC-4), AS (4 mm) vs HMC (AS-4), and AS (8 mm) vs HMC (AS-4), which is consistent with previous studies that evaluated forage vs grain feeding (Bowling et al., 1978; Schroeder et al., 1980; Jones, 1985; Tatum et al., 1988).

Percentage subcutaneous fat in the rib was greater ($P < .06$) in AS-fed cattle vs HMC-fed cattle for contrasts that compared AS (4 mm) vs HMC (RES) and AS (4 mm) vs HMC (AS-4) (Table 3). These results are similar to those of our previous work with Charolais-cross steers (Mandell et al., 1997) but are contrary to findings in Jones (1985), in which data were adjusted to the same proportion of subcutaneous fat. Greater ($P < .05$) intermuscular fat in grain-fed cattle than in AS-fed cattle (Table 3) with HMC (4 mm) vs AS (HMC-4), AS (4 mm) vs HMC (RES), and AS (4 mm) vs HMC (AS-4) are similar to findings by Jones (1985). Percentage body cavity fat was lower ($P < .02$) in HMC-fed cattle than in their forage counterparts for HMC (4 mm) vs AS (HMC-4) and AS (4 mm) vs HMC (AS-4) when slaughtered at similar times on feed. These results differ from those of previous work (Burson et al., 1980; Aberle et al., 1981) in which percentage kidney, pelvic, and heart fat in grain-fed cattle exceeded cattle fed low-energy diets at similar times on feed.

Numerical marbling score differed ($P < .002$) with the following contrasts that compared AS-fed cattle with HMC-fed cattle, HMC (4 mm) vs AS (HMC-4), HMC (AS-4) vs AS (8 mm), and AS (4 mm) vs HMC (AS-4) (Table 3). Many studies have reported lower marbling in forage-finished cattle relative to that in grain-finished cattle (Reagan et al., 1977; Aberle et al., 1981; Bidner et al., 1981; Rumsey et al., 1987; Schaake et al., 1993). Lean color was generally similar among diets except for lower ($P = .015$) lean color ratings for AS (4 mm) vs HMC (AS-4) owing to the presence of 4% dark cutters in AS-fed cattle. Smith (1990) has stated that forage finishing is not recommended in the United States because of darker muscle color and yellow fat color in forage-finished cattle compared with those in grain-finished cattle. Forage finishing may not necessarily be related to dark cutting found in the present trial because lean color in AS (8 mm)-fed cattle was similar ($P > .10$) to that in HMC-fed cattle that averaged 10 mm in grade fat. Diet did not affect fat color in the present trial nor color of lean and fat in our previous work (Mandell et al., 1997) on grain vs forage finishing.

Diet differences in palatability attributes could be affected by treatment differences in postmortem cooling rates and the incidence of cold shortening (Lee and Ashmore, 1985). Even though longissimus muscle temperature was approximately 2°C lower ($P < .10$) and longissimus muscle pH was approximately .2 pH unit higher ($P < .01$) for AS-fed than for HMC-fed cattle at 3 and 5 h after death (data not provided), linear and quadratic declines in temperature and pH were generally nonsignificant across dietary treatments.

Intramuscular fat content in HMC-fed cattle exceeded ($P < .02$) that in AS-fed cattle for most contrasts (Table 4). Forage vs grain feeding did not affect intramuscular fat content in previous studies (Oltjen et al., 1971; Reagan et al., 1977; Schroeder et al., 1980), but others (Dinius and Cross, 1978; Medeiros et al., 1987; Schaake et al., 1993) found grain feeding to increase intramuscular fat content relative to forage feeding. Warner-Bratzler shear force was not affected by forage vs grain feeding, agreeing with previous work (Dinius and Cross, 1978; Harrison et al., 1978; Crouse et al. 1984; Bidner et al., 1985, 1986; Schaake et al., 1993). However, others (Bowling et al., 1977; Leander et al., 1978; Schroeder et al., 1980; Aberle et al., 1981; Medeiros et al., 1987; Berry et al., 1988) found forage feeding to increase shear force as compared with grain feeding.

Soluble collagen content of LM was similar ($P > .10$) across diets (Table 4). Dietary energy content has influenced soluble collagen content in the past with lower soluble collagen content in beef fed low-energy diets (Crouse et al., 1985) or corn silage (Rompala and Jones, 1984) vs high-grain diets. In contrast, Aberle et al. (1981) and Dikeman et al. (1986) did not find any differences in soluble collagen content in beef from cattle fed low- and high-energy diets. Total cooking losses were lower ($P < .09$) for HMC (4 mm) cattle vs cattle on AS (HMC-4), AS (4 mm), or HMC (RES) treatments. Many studies have found similar cooking losses between forage- and grain-fed cattle (Bowling et al., 1977; Crouse et al., 1984; Dinius and Cross, 1978; Berry et al., 1988). In contrast, Hedrick et al. (1983) found greater cooking losses in grain-fed beef vs forage-fed cattle that differed drastically in backfat. Backfat was similar in the present study (Table 3), in which treatment differences in cooking losses were significant (Table 4).

Proportions of 14:0 and 16:1 were greater ($P < .01$) in HMC (AS-4) vs AS (4 mm) (Table 4) when slaughtered after 209 d on feed. In contrast, 14:0 and 16:1 did not differ between HMC (4 mm)- and AS (HMC-4)-fed cattle slaughtered after 120 d on feed. The discrepancy in significance of contrasts can partially be explained by findings of Duckett et al. (1993), which show that 112 d on grain were required to significantly change concentrations of 14:0 and 16:1 in LM relative to pasture-fed cattle. Proportions of 16:0 and 18:0 did not differ ($P > .10$) between most diets, in agreement with findings reported by Schroeder et al. (1980) and Mitchell et al. (1991). Stearic acid concentrations were greater ($P < .05$) in AS (8 mm)- vs HMC (AS-4)-fed cattle, which agrees with Boggs et al. (1989). Oleic acid concentrations in HMC-fed cattle exceeded ($P < .10$) AS-fed cattle between HMC (4 mm) and AS (HMC-4) and between AS (4 mm) and HMC (AS-4), and these results agree with the study of Mitchell et al. (1991). Linoleic acid concentrations were not affected by diet, which is supported by Schroeder et al. (1980) and Mitchell et al. (1991). Forage feeding increased ($P < .01$) 18:3 concentrations relative to grain feeding, as in Duckett et al. (1993).

Taste panel evaluation of LM roasts found no diet differences ($P > .10$) for the three “tenderness” attributes, softness, tenderness, and time spent chewing (Table 5). This agrees with past results from studies using trained taste panels (Reagan et al., 1977; Dinius and Cross, 1978; Crouse et al., 1984; Bidner et al., 1985, 1986; Fortin et al., 1985; Buchanan-Smith et al., 1989; Schaake et al., 1993). Many studies (Bowling et al., 1977, 1978; Harrison et al., 1978; Schroeder et al., 1980; Aberle et al., 1981; Hedrick et al., 1983) have compared palatability attributes in forage- vs grain-fed beef, in which large diet differences in backfat were present. These studies were confounded by either fatness or days on feed or both. The present study included confounding in the experimental design to examine forage- vs grain-fed beef at similar times on feed, although backfat could be confounded, or at similar levels of backfat even though days on feed could be confounded. Tenderness attributes were similar between diets regardless of finish or time on feed. Correlation analyses of pH data with Warner-Bratzler shear force and the three “tenderness” attributes found significant ($P < .05$) correlation coefficients (not in tabular form) across all cattle for 24-h pH and softness, r = –.28 ($P < .01$); tenderness, r = –.26 ($P < .01$); time spent chewing, r = .25 ($P < .01$); and shear force, r = .19 ($P < .05$).

Taste panel evaluation of LM roasts found no diet differences ($P > .10$) for initial and overall juiciness (Table 5), and this agrees with most studies that have examined forage vs grain feeding. Beef flavor was lower ($P < .05$) in AS-fed cattle vs HMC-fed cattle regardless of days on feed or amount of backfat finish. The converse was true for strong flavor with more ($P < .01$) intense strong flavor with forage feeding vs grain feeding. Diet differences in beef flavor and strong flavor in the present study were probably due in part to decreased concentrations of 18:3 and higher concentrations of 18:1 in grain-fed beef compared with forage-fed beef (Table 4). Oleic acid concentrations did not differ between HMC (AS-4) and AS (8 mm), but diet differences ($P < .05$) in 18:0 may contribute to diet differences in flavor; Melton et al. (1982b) found that ground beef with the most desirable flavor had lower concentrations of 18:0 and 18:3 in neutral

Table 4. Characteristics of longissimus muscle roasts as affected by diet in Limousin-cross steers fed either a 95% alfalfa silage (AS) ration or a 68% high-moisture corn (HMC) ration to various degrees of backfat finish

	Diet[b]							Probability of larger F-ratio for contrasts[c]				
Characteristic[a]	HMC (4 mm) (1)	AS (HMC-4) (2)	AS (4 mm) (3)	HMC (AS-4) (4)	HMC (RES) (5)	AS (8 mm) (6)	SE	1	2	3	4	5
Intramuscular fat, %[d]	2.61	1.68	2.72	4.04	2.94	3.15	.25	.0101	.4860	.0113	.5435	.0001
Warner-Bratzler shear, newtons	41.58	41.44	41.70	44.06	40.71	44.29	2.54	.9693	.9082	.9457	.7893	.4600
Soluble collagen, %	12.3	12.4	14.0	13.6	14.0	13.3	.9	.9497	.1376	.8358	.9849	.7094
Total cooking losses, %	18.16	20.27	21.88	21.13	20.47	20.52	.9	.0879	.0067	.6072	.2617	.4889
Drip losses, %	3.4	4.1	4.3	4.2	4.3	4.0	.5	.2690	.1177	.7522	.9352	.8615
Constituent fatty acids												
Myristic (14:0), %	1.6	1.1	1.4	2.5	1.9	1.9	.3	.2621	.7835	.1051	.2608	.0015
Palmitic (16:0), %	15.3	12.8	16.9	20.9	17.1	20.7	2.0	.3757	.4910	.9313	.9551	.1050
Palmitoleic (16:1), %	2.2	1.5	2.0	3.0	2.5	2.4	.3	.1395	.8888	.1584	.2608	.0076
Stearic (18:0), %	7.4	7.0	7.8	7.4	9.0	10.4	.9	.7334	.3886	.0221	.3639	.6941
Oleic (18:1), %	25.1	17.4	24.2	34.8	28.0	27.7	3.3	.0957	.7998	.1318	.4213	.0103
Linoleic (18:2), %	2.3	2.1	2.2	2.5	2.7	2.3	.2	.5067	.6286	.7082	.1043	.3211
Linolenic (18:3), %	.2	.6	.7	.2	.3	.7	.07	.0002	.0063	.0001	.0011	.0001

[a]Chemical analyses conducted on uncooked meat for chemical fat, soluble collagen, and constituent fatty acids. Shear test and determination of cooking losses conducted on cooked meat prepared for taste panel evaluation.

[b]Diets: 1, HMC (4 mm) = grain-fed cattle slaughtered at 4 mm backfat finish; 2, AS (HMC-4) =forage-fed cattle slaughtered regardless of finish when grain-fed cattle in Diet 1 achieved 4 mm backfat; 3, AS (4 mm) = forage-fed cattle slaughtered at 4 mm backfat finish; 4, HMC (AS-4) = grain-fed cattle slaughtered regardless of finish when forage-fed cattle in Diet 3 achieved 4 mm backfat; 5, HMC (RES) = grain-fed cattle fed at 75% of ad libitum intake of other grain-fed cattle and slaughtered at 4 mm backfat; 6, AS (8 mm) = forage-fed cattle slaughtered at 8 mm backfat finish.

[c]Contrasts: Contrast 1 = diet 1 vs diet 2; Contrast 2 = diet 1 vs diets 3 + 5; Contrast 3 = diet 4 vs diet 6; Contrast 4 = diet 3 vs diet 5; Contrast 5 = diet 3 vs diet 4.

[d]Intramuscular fat content is the percentage ether extractable fat (AOAC, 1990) and is expressed on a fresh weight basis.

and polar lipids and higher concentrations of 18:1 in neutral lipid. Melton (1983) noted that 20:3, 20:4, and 22:5 can promote undesirable flavors in forage-fed beef.

Chemical fat content in ground beef differed ($P < .05$) between grain- and forage-fed cattle (Table 6). These differences may be attributed to diet differences in LM fat content (Table 4) along with possible diet differences in DM content of added fat. Melton et al. (1982a) found diet differences in total lipid content but noted that total lipid content was not necessarily responsible for diet differences in flavor.

Ground beef from AS (8 mm) cattle had greater ($P < .05$) proportions of 14:0 and 16:1 than HMC (AS-4) cattle (Table 6); this is contrary to findings for 14:0 content of LM (Table 4). The literature finds forage feeding to increase (Marmer et al., 1984; Mitchell et al., 1991), decrease (Melton et al., 1982b), or not affect (Brown et al., 1979; Melton et al., 1982b) 14:0 content in specific lipid fractions from muscle or ground beef, whereas 16:1 decreased (Melton et al., 1982b) or increased (Brown et al., 1979) with forage feeding. Diet did not affect ($P > .10$) 16:0 in LM (Table 4), but ground beef from AS (8 mm)- and AS (4 mm)-fed cattle contained more 16:0 than ground beef from cattle fed HMC (AS-4) and HMC (RES), respectively. Grain feeding decreased (Melton et al., 1982b; Marmer et al., 1984), increased (Brown et al., 1979; Melton et al., 1982b), or did not affect (Brown et al., 1979; Schroeder et al., 1980; Marmer et al., 1984; Mitchell et al., 1991) 16:0 content in specific lipid fractions from muscle or ground beef. Discrepancies between proportions of 14:0 and 16:0 in LM vs ground beef may be due to fatty acid composition of subcutaneous and brisket fat.

Diets were similar ($P > .10$) for proportions of 18:0 and 18:2 except for increased 18:2 in HM (AS-4)- vs AS (4 mm)-fed cattle. Forage feeding increased 18:0 (Brown et al., 1979; Melton et al., 1982b) and decreased (Brown et al., 1979; Marmer et al., 1984) or did not affect (Brown et al., 1979) 18:2 vs grain feeding. Forage feeding decreased ($P < .10$) 18:1 in ground beef relative to grain feeding, agreeing with trends found with LM (Table 4). Previous work has found grain feeding to increase (Brown et al., 1979; Melton et al., 1982a), decrease (Brown et al., 1979), or not affect (Mitchell et al., 1991) 18:1 in specific lipid fractions. Grain feeding decreased ($P < .05$) proportions of 18:3 in ground beef, and this is supported by diet differences in LM (Table 4), and increased 18:3 found with forage feeding in previous work (Brown et al., 1979; Melton et al., 1982a; Marmer et al., 1984). In contrast, diet did not affect 18:3 in LM (Mitchell et al., 1991) or neutral lipid in semitendinosus muscle (Marmer et al., 1984).

Intensity scores from taste panel evaluation of ground beef are presented in Table 7. Greasy aroma

Table 5. Diet effects on taste panel evaluation of longissimus muscle roasts from Limousin-cross steers fed either a 95% alfalfa silage (AS) ration or a 68% high-moisture corn (HMC) ration to various degrees of backfat finish

Taste panel attribute[ab]	Diet[c] HMC (4 mm) (1)	AS (HMC-4) (2)	AS (4 mm) (3)	HMC (AS-4) (4)	HMC (RES) (5)	AS (8 mm) (6)	SE	Probability of larger F-ratio for contrasts[d] 1	2	3	4	5
Softness	5.83	5.45	5.81	5.96	5.77	5.51	.43	.5312	.9372	.4489	.9551	.7721
Initial juiciness	6.21	6.98	6.16	6.37	6.14	5.98	.35	.1290	.8868	.4223	.9708	.6251
Tenderness	5.84	5.29	5.81	5.92	5.59	5.37	.47	.4220	.8226	.3978	.7462	.8562
Juiciness	5.46	5.74	5.12	5.62	5.21	5.01	.31	.5356	.4477	.1560	.8546	.2048
Beef flavor	5.53	5.11	5.23	5.66	5.54	5.22	.15	.0496	.4536	.0383	.1475	.0204
Strong flavor	4.33	4.83	5.15	4.27	4.20	5.40	.22	.1188	.2242	.0006	.0043	.0022
Time spent chewing	3.69	4.27	3.60	3.38	3.89	3.95	.43	.3451	.9217	.3312	.6420	.6790

[a]Taste panel attributes: softness = force required to compress a sample with the molar teeth; initial juiciness = the amount of moisture released from the meat after five chews; tenderness = the force required to chew the sample using three additional chews after initial compression; juiciness = the overall impression of moistness perceived in the mouth after 10 chews; beef flavor = the amount of full meaty flavor present after eight chews; strong flavor = the amount of strong flavor at 6 to 7 chews; time spent chewing = time needed to chew the sample completely for swallowing.

[b]Taste panel attributes were evaluated using a scale from 0 to 10 with 0 always representing the left anchor and 10 representing the right anchor. The left anchor represented scoring of either very firm (softness), very tough (tenderness), very dry (initial juiciness), very weak (beef flavor), very dry (juiciness), very weak (strong flavor), and very little (time spent chewing), and the right anchor represented scoring of either very soft (softness), very tender (tenderness), very juicy (initial juiciness), very intense (beef flavor), very juicy (juiciness), very intense (strong flavor), and very chewy (time spent chewing).

[c]Diets: 1, HMC (4 mm) = grain-fed cattle slaughtered at 4 mm backfat finish; 2, AS (HMC-4) = forage-fed cattle slaughtered regardless of finish when grain-fed cattle in Diet 1 achieved 4 mm backfat; 3, AS (4 mm) = forage-fed cattle slaughtered at 4 mm backfat finish; 4, HMC (AS-4) = grain-fed cattle slaughtered regardless of finish when forage-fed cattle in Diet 3 achieved 4 mm backfat; 5, HMC (RES) = grain-fed cattle fed at 75% of ad libitum intake of other grain-fed cattle and slaughtered at 4 mm backfat; 6, AS (8 mm) = forage-fed cattle slaughtered at 8 mm backfat finish.

[d]Contrasts: Contrast 1 = diet 1 vs diet 2; Contrast 2 = diet 1 vs diets 3 + 5; Contrast 3 = diet 4 vs diet 6; Contrast 4 = diet 3 vs diet 5; Contrast 5 = diet 3 vs diet 4.

Table 6. Quantitative and qualitative fat composition of ground beef as affected by diet from Limousin-cross steers fed either a 95% alfalfa silage (AS) ration or a 68% high-moisture corn (HMC) ration to various degrees of backfat finish

	Diet[a]							Probability of larger F-ratio for contrasts[b]				
Item	HMC (4 mm) (1)	AS (HMC-4) (2)	AS (4 mm) (3)	HMC (AS-4) (4)	HMC (RES) (5)	AS (8 mm) (6)	SE	1	2	3	4	5
Chemical fat content, %[c]	23.4	20.2	22.0	26.5	22.8	24.6	.6	.0005	.2112	.0317	.3859	.0001
Constituent fatty acid												
Myristic (14:0), %	7.3	6.7	6.9	7.2	6.8	8.1	.3	.1901	.2569	.0193	.9406	.2678
Palmitic (16:0), %	46.1	45.9	49.8	48.0	44.1	56.4	1.8	.9537	.7154	.0009	.0323	.4508
Palmitoleic (16:1), %	7.7	7.6	8.5	8.3	7.6	9.7	.4	.9029	.4522	.0146	.1150	.5992
Stearic (18:0), %	21.2	21.9	19.8	21.7	19.1	24.1	1.6	.7560	.4171	.2748	.7846	.3604
Oleic (18:1), %	69.2	61.9	65.7	80.0	67.5	73.6	2.8	.0705	.4628	.0948	.6671	.0001
Linoleic (18:2), %	2.4	2.2	2.2	3.1	2.7	2.5	.3	.5387	.8956	.1032	.2218	.0130
Linolenic (18:3), %	.4	1.0	1.2	.3	.2	1.2	.1	.0005	.0288	.0001	.0001	.0001

[a]Diets: 1, HMC (4 mm) = grain-fed cattle slaughtered at 4 mm backfat finish; 2, AS (HMC-4) = forage-fed cattle slaughtered regardless of finish when grain-fed cattle in Diet 1 achieved 4 mm backfat; 3, AS (4 mm) = forage-fed cattle slaughtered at 4 mm backfat finish; 4, HMC (AS-4) = grain-fed cattle slaughtered regardless of finish when forage-fed cattle in Diet 3 achieved 4 mm backfat; 5, HMC (RES) = grain-fed cattle fed at 75% of ad libitum intake of other grain-fed cattle and slaughtered at 4 mm backfat; 6, AS (8 mm) = forage-fed cattle slaughtered at 8 mm backfat finish.

[b]Contrasts: Contrast 1 = diet 1 vs diet 2; Contrast 2 = diet 1 vs diets 3 + 5; Contrast 3 = diet 4 vs diet 6; Contrast 4 = diet 3 vs diet 5; Contrast 5 = diet 3 vs diet 4.

[c]Chemical fat content is the percentage ether extractable fat (AOAC, 1990) and is expressed on a fresh weight basis.

was similar across most diets except for lower ($P < .05$) aroma in ground beef made from AS (8 mm)- vs HMC (AS-4)-fed cattle. Increased greasy aroma in HMC (AS-4) cattle may be due to diet differences ($P < .10$) in 16:1 and 18:1 contents of ground beef between HMC (AS-4) and AS (8 mm) (Table 6); correlation analyses showed that greasy aroma was positively correlated with 18:1 ($r = .20$, $P < .05$) and 16:1 ($r = .22$, $P < .05$). This theory is not supported by nonsignificant differences in greasy aroma between AS (4 mm) and HMC (AS-4), when diet differences in 18:1 exist and concentrations of 16:1 are similar. Proportions of 14:0 and 16:0 differed ($P < .05$) between HMC (AS-4) and AS (8 mm), but these two fatty acids were not correlated with greasy aroma across all diets or within HMC (AS-4) or AS (8 mm).

Metallic aroma differed ($P < .05$) between forage and grain feeding with increased scores for AS (4 mm)- vs HMC (AS-4)- and HMC (RES)-fed cattle. Diet differences in 18:1 and 18:3 may be responsible because metallic aroma was negatively correlated to 18:1 ($r = -.21$, $P < .05$) and positively correlated to 18:3 ($r = .30$, $P < .01$). Metallic aroma was negatively correlated ($P < .05$) to beef fat aroma, beef flavor, and sweet flavor but positively correlated ($P < .02$) to grassy aroma, sour and liver flavors, and metallic aftertaste. Beef fat aroma did not differ between diets but was positively correlated ($P < .10$) to beef and sweet flavors, 14:0, 16:0, 16:1, and 18:1 and negatively correlated ($P < .01$) to metallic and grassy aromas, sour flavor, and metallic aftertaste. Melton et al. (1982a) found cooked beef fat aroma to be positively correlated to 14:1, 16:1, 17:1, and 18:1 but negatively correlated to 15:0, 18:0, 18:3, 19:1, 20:1, and 20:4.

Forage feeding increased ($P < .10$) grassy aroma for all contrasts that directly compared AS-fed cattle vs HMC-fed cattle. Grassy aroma was positively correlated ($P < .05$) with 14:0, 16:0, 18:3, metallic aroma, sour and liver flavors, and metallic aftertaste and was negatively correlated ($P < .05$) to beef and salt flavors and beef fat aroma. Melton et al. (1982a) found milky-oily aroma to decrease as days on corn increased, whereas this aroma was positively correlated to 18:0, 18:3, and sour flavor and was negatively correlated to cooked beef aroma and flavor and liver flavor. Proportions of 18:0 were probably not a factor in the present study owing to nonsignificant diet differences, but 18:0 decreased with increasing days on corn for Melton et al. (1982a).

Sour flavor was similar across most diets except for greater ($P < .05$) sour flavor in ground beef made from AS (8 mm)- vs HMC (AS-4)-fed cattle. Sour flavor was positively correlated ($P < .05$) with 14:0, metallic and grassy aromas, liver flavor, and metallic aftertaste but negatively correlated ($P < .01$) to beef fat aroma and flavor and sweet flavor. Melton et al. (1982a) found sour flavor positively correlated to 18:0 and 18:3 and negatively correlated to 16:1 and 18:1. Diet differences in sour flavor in the present study were probably due to diet differences ($P < .10$) in 14:0

Table 7. Diet effects on taste panel evaluation of ground beef from Limousin-cross steers fed either a 95% alfalfa silage (AS) ration or a 68% high-moisture corn (HMC) ration to various degrees of backfat (BF) finish

Taste panel attribute[a]	Diet[b] HMC (4 mm) (1)	AS (HMC-4) (2)	AS (4 mm) (3)	HMC (AS-4) (4)	HMC (RES) (5)	AS (8 mm) (6)	SE	Probability of larger F-ratio for contrasts[c] 1	2	3	4	5
Greasy aroma	4.63	4.50	4.59	4.69	4.62	4.40	.10	.3604	.7997	.0369	.8363	.4154
Metallic aroma	4.22	4.46	4.46	3.95	4.00	4.15	.14	.2202	.9423	.2742	.0214	.0036
Beef fat aroma	4.15	3.92	4.22	4.38	4.03	4.17	.13	.2326	.8792	.2553	.3248	.3510
Grassy aroma	2.72	3.02	3.31	2.69	2.63	3.25	.13	.0989	.1187	.0017	.0003	.0002
Sour flavor	3.89	3.94	3.64	3.45	3.45	3.91	.18	.8419	.1388	.0588	.4483	.3841
Beef flavor	4.03	3.75	3.91	4.40	4.25	4.18	.16	.2158	.7969	.3199	.1407	.0164
Sweet flavor	2.20	1.77	1.90	2.12	2.01	2.15	.13	.0245	.1549	.8877	.5757	.1920
Salty flavor	2.22	2.10	2.05	2.14	2.25	2.19	.08	.3000	.5175	.6938	.0784	.3391
Liver flavor	3.20	3.08	3.38	3.11	3.00	3.14	.14	.5314	.9598	.8468	.0614	.1197
Metallic after taste	3.78	4.13	4.11	3.92	4.12	4.05	.17	.1514	.1189	.5558	.9743	.3496
Greasy after taste	4.32	4.10	4.18	4.35	4.25	4.18	.11	.1692	.4812	.2754	.6418	.2365

[a]Taste panel attributes were evaluated using a scale from 0 to 10: 0 always represented the left anchor with scoring of either none for all attributes except beef flavor, for which the left anchor was very weak. A score of 10 represented the right anchor with scoring of very intense for the specific attribute evaluated.

[b]Diets: 1, HMC (4 mm) = grain-fed cattle slaughtered at 4 mm backfat finish; 2, AS (HMC-4) = forage-fed cattle slaughtered regardless of finish when grain-fed cattle in Diet 1 achieved 4 mm backfat; 3, AS (4 mm) = forage-fed cattle slaughtered at 4 mm backfat finish; 4, HMC (AS-4) = grain-fed cattle slaughtered regardless of finish when forage-fed cattle in Diet 3 achieved 4 mm backfat; 5, HMC(RES) = grain-fed cattle fed at 75% of ad libitum intake of other grain-fed cattle and slaughtered at 4 mm backfat; 6, AS (8 mm) = forage-fed cattle slaughtered at 8 mm backfat finish.

[c]Contrasts: Contrast 1 = diet 1 vs diet 2; Contrast 2 = diet 1 vs diets 3 + 5; Contrast 3 = diet 4 vs diet 6; Contrast 4 = diet 3 vs diet 5; Contrast 5 = diet 3 vs diet 4.

and 18:1 contents (Table 6). Sour flavor was associated with grass-fed beef according to Melton et al. (1982b). Larick and Turner (1990) did not find any fatty acid in neutral lipid of ground beef to be correlated with sour flavor, but sour flavor increased with days in the feedlot in contrast to present findings. Grass vs grain feeding did not affect sour flavor in the study by Maruri and Larick (1992), and forage-fed beef was characterized by a gamy/stale off-flavor.

Beef flavor in HMC (AS-4)-fed cattle exceeded ($P < .05$) AS (4 mm)-fed cattle. These cattle were slaughtered after similar time on feed. Diet differences in beef flavor were probably due to diet differences ($P < .01$) in fatty acid contents with 18:1 greater in HMC (AS-4) and 18:3 greater in AS (4 mm). Beef flavor was positively correlated ($P < .05$) to 18:1, sweet flavor, beef fat aroma and negatively correlated ($P < .05$) to 18:3, liver and sour flavors, metallic and grassy aromas, and metallic and greasy aftertastes. Melton et al. (1982a) found cooked beef fat flavor to be positively correlated to 16:1, 18:1, cooked beef fat aroma, and liver flavor and negatively correlated to sour flavor, milky-oily aroma and flavor, 18:0, and 18:3. Larick and Turner (1990) found cooked beef fat flavor to be positively correlated to 14:0, 16:0, 16:1, and 18:1 concentrations of neutral lipid. Nonsignificant differences in beef flavor between HMC (AS-4) and AS (8 mm) may be due to increased ($P < .05$) concentrations of 16:0 and 16:1 with AS (8 mm)- vs HMC (AS-4)-fed cattle. Grass-fed beef had lower beef flavor scores than grain-fed beef according to Maruri and Larick (1992).

Sweet flavor was lower ($P < .05$) with AS (HMC-4)- vs HMC (4 mm)-fed cattle. Sweet flavor was positively correlated ($P < .05$) to 16:0, 16:1, 18:0, 18:1, 18:2, beef fat aroma, and beef flavor, and negatively correlated ($P < .05$) to metallic aroma and aftertaste and sour flavor. Oleic acid was greater ($P < .10$) in HMC (4 mm) vs AS (HMC-4), but the converse was true for 18:3. Larick and Turner (1990) did not find any fatty acids in neutral lipid to be correlated to sweet flavor. Diet differences in sweet flavor may be due to greater 18:1 in HMC (4 mm) vs AS (HMC-4) because all other fatty acids were similar. Larick and Turner (1990) found sweet flavor to decrease with increasing days in the feedlot.

Salty and liver flavors differed between AS (4 mm)- and HMC(RES)-fed cattle, with increased ($P < .10$) salty flavor in HMC(RES) and increased ($P < .10$) liver flavor in AS (4 mm). Salty flavor was negatively correlated ($P < .05$) to grassy aroma and positively correlated ($P < .10$) to 18:2. Liver flavor was positively correlated ($P < .05$) to metallic and grassy aroma, sour flavor, and metallic and greasy aftertastes and negatively correlated ($P < .01$) to beef fat flavor. In contrast, Melton et al. (1982a) found liver flavor to be positively correlated to 16:1 and cooked beef fat flavor and negatively correlated to 18:0 and milky-oily aroma and flavor. Palmitoleic and oleic acid concentrations did not differ between AS (4 mm) and HMC (RES).

Metallic and greasy aftertastes did not differ among diets (Table 7). Metallic aftertaste was positively correlated ($P < .05$) to metallic and grassy aromas and to sour and liver flavors but was negatively correlated ($P < .05$) to beef fat aroma and sour and beef flavors. Greasy aftertaste was positively correlated ($P < .05$) to greasy aroma, sweet and liver flavors, 14:0, 16:0, 18:0, and 18:1 but negatively correlated ($P < .05$) to beef flavor.

The present study is limited in that total lipid in LM and ground beef were analyzed for individual fatty acids. Total lipid was not separated into neutral and polar lipids so that fatty acid analysis of phospholipids could be conducted. Nitrogen moiety of phospholipid and degree of unsaturation influence off-flavor development after cooking (Larick and Turner, 1990). Polyunsaturated acid profiles of individual phospholipids rather than the fatty acid profiles of total lipid should be examined for off-flavor and warmed-over-flavor (Larick et al., 1989).

Further research is warranted to evaluate forage finishing and the effect of slaughter end point on beef quality. Forage finishing may be a viable means to produce quality beef provided economics of feeding favors the producer. Forage finishing of cattle with predominantly Continental breeding may result in carcasses with minimum levels of finish.

Implications

Alternative methods of finishing cattle may be viable for the beef industry as long as there are profits for producers and quality satisfies consumers. Forage finishing can satisfy tenderness demands of consumers, but intensity of beef flavor still differs from grain-fed beef. Given recent fluctuations in grain prices, research must continue to investigate alternative methods of finishing cattle.

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