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Fatty Acid Composition, Proximate Analysis, and Consumer Sensory Evaluation of United States Retail Grass-Fed Ground Beef[1]

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Abstract: The objective of this study was to evaluate the chemical composition, consumer liking, and consumer acceptability of ground beef with 2 finishing diets. Three ground beef treatments were used in this study and included grass-fed, grain-fed Angus, and grain-fed commodity beef. Ground beef samples were evaluated for consumer sensory response, pH, proximate composition, and fatty acid composition. Grain-fed samples were rated higher ($P < 0.01$) for overall liking compared to grass-fed samples. Consumers found tenderness and juiciness similar ($P > 0.05$) for all 3 types of ground beef. Consumers preferred ($P < 0.05$) Angus over grass-fed ground beef with a flavor acceptability of 83.3 and 73.9%, respectively; and 94.9 and 82.5%, respectively, for overall acceptability. Commodity ground beef had a similar ($P > 0.05$) flavor acceptability and overall acceptability to Angus and grass-fed ground beef. Grass-fed, Angus, and commodity ground beef were similar ($P > 0.05$) for moisture, fat, and protein content. Commodity ground beef had a higher pH ($P < 0.05$) than Angus and grass-fed ground beef. Samples of ground beef from the 2 grain-fed treatments had greater ($P < 0.05$) total saturated fatty acids (SFA) than grass-fed samples; however, ground beef from grass-fed cattle had higher monounsaturated fatty acids (MUFA; $P < 0.01$) than the grain-fed treatments. Total polyunsaturated fatty acids (PUFA) was similar ($P > 0.01$) across all treatments. Omega-3 fatty acids were found in the greatest ($P < 0.05$) proportions in samples from grass-fed beef. Additionally, the omega-6:omega-3 ratio for grass-fed ground beef was lower ($P < 0.05$) than grain-fed source. Angus and commodity ground beef were more palatable, and there was no evidence of higher PUFA in grass-fed ground beef.

Keywords: Angus, consumer, fatty acids, grass-fed, ground beef
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Introduction

Ground beef is considered one of the major sources of animal protein in the United States, and is one of the most widely consumed beef commodities across the United States. In most US retail stores, consumers can choose between grain-fed and grass-fed ground beef, but consumers prefer grain-fed ground beef due to the flavor and overall palatability gained on a grain-based diet (Wood et al., 2003). However, sustainable production, animal welfare, and low-fat products often drive consumer purchasing decisions, resulting in an increased demand for grass-fed ground beef (United States Department of Agriculture, Agriculture Marketing Service [USDA-AMS], 2007).

To date, there are no federal standards regarding grass-fed labeling (USDA-AMS, 2016). However, there are several ways to label grass-fed meat. According to the American Grassfed Association (AGA, 2018) and its Grassfed Ruminant Standards, a grass-fed beef cattle program requires that ruminant animals are strictly fed grass and forage as their sole energy sources of feed. Cattle must have continuous

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access to open pasture from birth to the finishing stage (AGA, 2018). Meat products from animals following AGA guidelines are permitted to be marketed as AGA grass-fed meat.

It is recommended an omega-6:omega-3 ratio (4:1) to help decrease unfavorable health conditions (Simopoulos, 2002). Grass-fed ground beef contains 3 times more omega-3 fatty acids than traditional grain-fed ground beef; however, there is no evidence to support that choosing grass-fed beef is a healthier choice for consumers compared to traditional ground beef (Smith, 2013). From an economic point of view, grass-fed beef has a relatively higher price than grain-fed beef. For instance, the USDA-AMS National Monthly Grass Fed Beef Report (USDA-AMS, 2018) reported that commodity ribeye steaks averaged $3.62/kg at the retail store while the grass-fed premium was priced 2.37 times higher. Researchers have studied the differences in flavor profiles between grass-fed and grain-fed beef and have found that grass-fed beef has a negative effect on consumer flavor acceptability (Killinger et al., 2004; Kerth et al., 2007; Mandell, 1998). Additionally, beef that has been produced on grass have a different fatty acid composition, including a higher proportion of polyunsaturated fatty acids (PUFA) than grain-fed cattle, which can decrease flavor desirability of meat (Melton, 1990). The overall objective of this study was to evaluate consumer acceptance of grass-fed ground beef compared to commodity and Angus ground beef.

Materials and Methods

Product preparation

For this study, 80% lean and 20% fat vacuum packaged chubs of Angus, commodity, and 85% lean and 15% fat frozen chubs of grass-fed ground beef, were purchased from a local retail store in Manhattan, KS. As a result, the postmortem age and supplier of the ground beef was unknown. All products were labeled as "Product of U.S." The term "commodity" is used to define USDA Select meat, which is commonly found in retail stores throughout the United States as the common beef for everyday use (Griffin and Savell, 2018). Grass-fed ground beef was labeled as "Meat from animals 100% grass-fed." For each treatment, replicates (n = 14) from different production lots with each replicate consisting of 2.26 kg-bag were used. Upon arrival, product was stored in their original packaging in a –40°C research freezer for up to 30 d in the Kansas State University (KSU) Meat Laboratory. The ground beef was thawed for 24 h at 2 to 4°C. Two 113-g ground beef patties with a thickness between 1.10 and 1.27 cm (AMSA, 2016) were formed from each independent unit, packed separately, and used for consumer evaluation. Ground beef patties were manually formed using an acrylic patty former with round template that was 10.80 cm in diameter. After patty manufacturing, samples were placed on trays, crust frozen, and then vacuum packaged and stored at –40°C until used for panels. The remaining product was vacuum packaged, frozen at –40°C until analyzed for proximate analysis and fatty acid (FA) profile determination.

Consumer sensory evaluation

Consumer sensory panels were conducted in Weber Hall at KSU, Manhattan, KS, following the AMSA research guidelines (AMSA, 2016). Ground beef chubs were thawed for 24 h at 2 to 4°C prior to sensory evaluation. Consumer panelists (n = 98) were recruited from Manhattan, KS, and adjacent communities. This study was conducted over six 1-h sessions and 18 panelists were present at each panel session. Electronic tablets (Model 5709 HP Steam 7; Hewlett-Packard, Palo Alto, CA) were provided to consumers to record a panelist response (Qualtrics Software, Provo, UT). In addition, panelists were provided with a napkin, plastic fork, plastic knife, expectorant cup, glass of water, and 3 unsalted crackers and apple juice to be used to clear their palate in between each sample. Panelists completed a demographic survey, which included general questions on age, sex, income, etc., and they were asked to give information about their knowledge on Omega-3 rich ground beef products and if they were willing to pay extra for this commodity. These data was loaded onto the tablet and used the ballot pages on the tablet for each sample to be evaluated. Ground beef patties were cooked on a clamshell grill (Cuisinart Griddler Deluxe, Model GR-150, East Windsor, NJ) to an internal temperature of 74°C using a probe thermometer (Super-Fast Thermopen, ThermoWorks, American Fork, UT). Following cooking, ground beef patties were manually cut with a knife into 4 wedge-shaped pieces. One piece was placed on a coded paper plate. Each panelist evaluated 6 samples (2 per treatment) in a random order. Each panelist evaluated samples using a continuous line scale anchored at both ends with descriptive terms. Ground beef patties were evaluated for tenderness, juiciness, flavor liking, texture liking, and overall liking. For all samples, the 0 anchors were set as extremely tough, extremely dry, and dislike extremely; the 50 anchors were labeled as neither tough nor tender, neither dry nor juicy, and neither like nor dislike; and the 100 anchors were identified as extremely tender, extremely juicy, and like extremely. Additionally, consumers rated each sample as either acceptable or unacceptable for each sensory trait assessed.

pH and proximate analysis

A calibrated pH probe (Model FC232, Hanna Instruments Inc., Woonsocket, RI) with a pH meter (Model HI 99163, Hanna Instruments Inc.) was inserted in duplicate to determine the pH of ground beef. Each sample of ground beef treatments was prepared for moisture, fat, and protein (proximate analysis) determination by freezing pieces of the samples through immersion in liquid nitrogen, homogenizing the frozen pieces using a blender (Model 33BL79, Waring Products, New Hartford, CT) and placing the powdered sample in 11.4 × 22.9 cm plastic labeled Whirl-Pak bags (Fisher Scientific, Fair Lawn, NJ). The homogeneous powder was stored at –80°C until used for proximate analysis determination. The Association of Analytical Communities procedures (AOAC Official Method PVM-1:2003 MEAT) were used to analyze moisture and crude fat content by the SMART system 5 (CEM Corp., NC). Protein analysis was conducted using the LECO FP-2000 Protein/Nitrogen Analyzer (Model 602–600, LECO Corp., St. Joseph, MI). The combustion method (TruMac N Nitrogen/Protein determination Instruction manual, 2014, LECO Corp.) was used. The percent of nitrogen was then multiplied by 6.25 to determine protein content.

Fatty acid methyl ester analyses

Homogeneous powder from each treatment were used for fatty acid methyl ester (FAME) determination. This procedure was performed as described by Sukhija and Palmquist (1988), which utilizes a 1-step extraction/transesterification method. Briefly, a 200 mg freeze-dried ground beef sample was used and transesterified in methanol:benezene:acetyl chloride (20:27:3, vol/vol) and 2 mL of internal standard (methyl tridecanoate; 2.0 mg of fatty acid C:13:0/mL of benzene). Agilent Gas Chromatograph (model 7890A; Agilent Technologies, Inc., Santa Clara, CA) was utilized to determine FAME. The gas chromatograph machine was equipped with a 100 m × 0.25 mm × 0.20μ (id) fused silica capillary column (SP-2560 Supelco Inc., Bellefonte, PA). Column oven temperature was held at 100°C for 5 min, increased to 240°C at a rate of 3°C/min, and held for 20 min at 240°C. Injection and detector temperature were 250°C with a flow rate of 1 mL/minute. A genuine external standard Supelco 37 (47885-U Supelco; Sigma-Aldrich, St. Louis, MO) was used to identify individual FA after comparing retention times. Subsequently, individual FAME were calculated as a percentage of total FAME. To quantify total FA content, an internal standard is recommended according to the Sukhija and Palmquist method (Sukhija and Palmquist, 1988). Additionally, conjugated linoleic acid (CLA) isomers were identified with an extra composite standard mix of CLAs, C18:1 cis-11, and C18:1 trans-11 (Matreye #s 1255, 1257, 1256, 1254, 1267, 1263). This standard was not quantitative and was used for peak ID only. Response factor (RF) for all CLAs was taken from the C18:2 peak average in the 37 FAME standard and RF for C18:1 cis-11 and C18:1 trans-11 were taken from C18:1 cis-9 and C18:1 trans-9, respectively. The C18:1 trans-isomers were not well separated and were used for considered estimates. DPA (C22:5 n-3) was identified at an earlier date using a Marine PUFA standard (Sigma #47033) and uses the same RF as DHA (C22:6 n-3).

Statistical analysis

Data were analyzed using SAS version 9.4 (SAS Inst. Inc., Cary, NC). Treatment effects were evaluated using the PROC GLIMMIX procedure in SAS. Data were analyzed as a complete block design with each chub from each treatment treated as the blocking factor. In the model, the Kenward–Roger approximation was utilized. If a treatment effect was found to be significant ($P < 0.05$), the PDIFF option was used for mean separation. Additionally, a binomial model was used to analyze consumer acceptability scores. Differences were considered significant at ($P < 0.05$) The CORR procedure of SAS was used to determine Pearson correlation coefficients.

Results and Discussion

Consumer demographics

The demographic characteristics of the 98 consumers who evaluated the ground beef samples are shown in Table 1. More men (59%) than women (41%) participated in the sensory panel. More than 60% of all participants were Caucasian/white and 55.3% were single. More than 50% of consumers (51.6%) had an annual household income of $75,000 or more. In addition, 72.2% of consumers who were surveyed had some college/technical experience, completed college, or post graduate experience. Just over 35% of the con-

Table 1. Demographic characteristics of consumers (n = 98) who participated in sensory panels to analyze Angus, commodity, and grass-fed ground beef samples

Characteristic	Response	Percentage of consumers
Gender	Male	59.0
	Female	41.0
Household size	1 person	16.7
	2 people	21.9
	3 people	17.7
	4 people	22.9
	5 people	8.3
	6 people	6.3
	Over 6 people	6.3
Marital status	Single	55.3
	Married	44.7
Age group	18 to 24	36.5
	25 to 34	11.5
	35 to 44	11.5
	45 to 54	16.7
	55 to 64	18.8
	Greater than 65	5.2
Ethnic origin	African-American	14.6
	Asian	1.0
	Caucasian/White	62.5
	Hispanic	5.2
	Native American	5.2
	Other	2.1
	Mixed Race	9.4
Annual household income, $	< $25,000	10.5
	$25,000 to $34,999	7.4
	$35,000 to $49,999	14.7
	$50,000 to $74,999	15.8
	$75,000 to $99,999	15.8
	$100,000 to $149,999	19.0
	$150,000 to $199,999	10.5
	> $199,999	6.3
Highest level of education completed	Non-high school graduate	5.2
	High school graduate	22.7
	Some college/technical school	42.3
	College graduate	16.5
	Post graduate	13.4
Weekly ground beef consumption	0 to 3 times	12.8
	4 to 6 times	27.7
	7 to 9 times	14.9
	10 to 12 times	21.3
	13 to 15 times	20.2
	16 to 18 times	2.1
	19 to 21 times	1.1
Were consumers aware of omega 3s?	Yes	69.1
	No	30.9
Were consumers willing to pay a premium for nutritionally better with omega 3s?	Yes	79.6
	No	20.4
Avg. perception of health benefits (0 = no benefit; 100 = extremely beneficial): 71.9 ± 21.1		
Avg. premium willing to pay: $0.86 ± $0.49		

sumers (36.5%) were aged 18 to 24 yr old. More than 87.3% of panelists consumed a ground beef product from 4 to 21 times per week. When asked if they were aware of omega 3s, 69.1% responded that they were, and 79.6% responded that they would be willing to pay extra ($0.86 ± $0.49) to purchase omega 3 rich ground beef products.

Table 2. Least squares means for consumer (n = 98) palatability ratings[1] for Angus, commodity, and grass-fed ground beef

Treatment	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking
Angus	64.7	69.7	59.8	63.2	65.2[a]
Commodity	66.5	68.0	61.2	61.5	66.2[a]
Grass-fed	64.0	65.9	54.1	57.2	56.4[b]
SEM[2]	2.07	1.96	2.15	2.1	2.12
P-value	0.57	0.40	0.06	0.06	< 0.01

[a,b]Means in the same column lacking a common superscript differ (P < 0.05).

[1]Sensory scores: 0 = not tender/juicy, dislike flavor/texture/overall extremely; 50 = neither tough nor tender, neither dry nor juicy, or neither like nor dislike flavor/texture/overall; 100 = very tender/juicy, like flavor/texture/overall extremely.

[2]Pooled standard error of the least squares means.

Consumer sensory evaluation

Least squares means for consumer palatability ratings for each treatment of ground beef are found in Table 2. Angus and commodity ground beef were rated higher (P < 0.05) for overall liking compared to grass-fed ground beef. Consumers found tenderness and juiciness palatability ratings to be similar (P > 0.05) for all 3 types of ground beef. The percentage of ground beef samples rated as acceptable for each trait by consumers is shown in Table 3. Consumers preferred (P < 0.05) Angus over grass-fed ground beef with a flavor acceptability of 83.3 and 73.9%, respectively; and 94.9 and 82.5%, respectively, for overall acceptability. Commodity ground beef had a similar (P > 0.05) flavor acceptability and overall acceptability to Angus and grass-fed ground beef. Consumers indicated no difference (P > 0.05) for tenderness acceptability, juiciness acceptability, and texture acceptability among the 3 ground beef treatments. It is well documented the flavor differences between corn-based and grass-fed meat (Hedrick et al., 1983; Crouse et al., 1984; Rouquette et al., 2014). Particularly, grass-fed beef had a different fatty acid composition than grain-fed cattle, which altered palatability attributes such as flavor (Melton, 1990). These results were also similar as those found by O'Quinn et al. (2016), who reported that ground beef from conventionally raised cattle was more desirable than grass-fed cattle.

pH and proximate analysis

Ground beef proximate composition and pH results are presented in Table 4. Commodity beef pH was greater (P < 0.01) than Angus, and both grain-fed treatments had higher (P < 0.01) than grass-fed. Conversely, other studies demonstrated grass-finished beef had higher pH than

Table 3. Percentage of Angus, commodity, and grass-fed ground beef samples considered acceptable for palatability traits by consumers (n = 98)

Treatment	Tenderness acceptability	Juiciness acceptability	Flavor acceptability	Texture acceptability	Overall acceptability
Angus	91.6	92.4	83.3[ab]	90.5	94.9[a]
Commodity	84.7	91.4	90.6[a]	83.8	91.8[ab]
Grass-fed	84.7	87.4	73.9[b]	83.8	82.5[b]
SEM[1]	4.27	3.84	4.47	4.88	4.11
P-value	0.26	0.46	0.02	0.28	0.03

[a,b]Means in the same column lacking a common superscript differ (P < 0.05).

[1]Pooled standard error of the least squares means.

grain-finished beef (Wulf et al., 1997; Rouquette et al., 2014). The label of commodity ground beef stated the addition of lean finely textured beef, which increases the ultimate pH of beef due to high ammonia levels used in the process to separate lean from fat. In addition, the use of different muscles, including muscles from the chuck and round, in manufacturing ground beef can also affect its ultimate pH (Von Seggern et al., 2005). Troutt et al. (1992) found no differences in pH between raw ground beef patties containing 15 and 20% fat. Treatment had no effect on moisture content (P > 0.05) or fat content (P > 0.05). Packages of ground beef used in this study stated that Angus and commodity ground beef was 80% lean (containing 20% fat). Grass-fed ground beef, however, was packaged with a label stating 85% lean (containing 15% fat). After examining fat content levels, the results indicated Angus, commodity, and grass-fed ground beef had 19.83, 19.81, and 15.78% fat content, respectively. These findings are in compliance with the 20% deviation limit for ground beef label claims on fat content (Howe et al., 2007). In a similar study, Melton et al. (1982a) found no significant differences for moisture or fat content between ground beef from grass-fed and grain-fed cattle. However, Rouquette et al. (2014) found moisture content of *longissimus* steaks from grass-fed cattle was higher than those from grain-finished cattle. Treatment had no

Table 4. Moisture, fat, protein content, and pH of Angus, commodity, and grass-fed ground beef

Treatment	Fat, %	Moisture, %	Protein, %	pH
Angus	19.8	61.5	18.0	5.8[b]
Commodity	19.8	61.6	17.6	6.0[a]
Grass-fed	15.7	64.7	18.7	5.6[c]
SEM[1]	1.48	1.08	0.34	0.04
P-value	0.16	0.12	0.15	< 0.01

[a–c]Least squares means for the same product in the same column lacking a common superscript differ (P < 0.05).

[1]Pooled standard error of the least squares means.

Table 5. Least squares means of percentage of fatty acids in Angus, commodity, and grass-fed ground beef

	Treatment				
Fatty acid	Grass-fed	Commodity	Angus	SEM[1]	*P*-value
8:0	0.01	0.01	0.01	< 0.01	0.77
10:0	0.05[c]	0.06[a]	0.05[b]	< 0.01	< 0.01
12:0	0.08[b]	0.09[a]	0.09[a]	< 0.01	< 0.01
14:0	3.18[b]	3.41[a]	3.44[a]	0.03	< 0.01
14:1	1.15[a]	0.95[b]	0.98[b]	0.03	< 0.01
15:0	0.48[b]	0.54[a]	0.53[a]	0.01	< 0.01
15:1	0.02[a]	0.01[b]	0.01[b]	< 0.01	< 0.01
16:0	26.05	26.233	26.31	0.12	0.30
16:1	4.67[a]	4.84[b]	4.92[b]	0.09	< 0.01
17:0	1.51[b]	1.75[a]	1.72[a]	0.03	< 0.01
18:0	12.41[b]	14.15[a]	14.13[a]	0.25	< 0.01
18:1 trans-9	0.32[b]	0.63[a]	0.61[a]	0.04	< 0.01
18:1 trans-11	1.13	1.05	1.08	0.07	0.73
18:1 cis-9	42.23[a]	40.61[b]	40.46[b]	0.33	< 0.01
18:1 cis-11	1.91[a]	1.70[b]	1.70[b]	0.03	< 0.01
18:2n-6 cis	2.59[b]	3.02[a]	3.04[a]	0.08	< 0.01
18:2n-6 trans	0.01[b]	0.02[a]	0.02[a]	< 0.01	< 0.01
18:3n-3	0.28	0.22	0.21	0.02	0.09
18:3n-6 cis	0.02[a]	0.01[b]	0.01[b]	< 0.01	< 0.01
20:0	2.59[b]	3.02[a]	3.04[a]	0.08	< 0.01
20:1	0.23[a]	0.21[b]	0.21[b]	< 0.01	< 0.01
20:2	0.03[b]	0.04[a]	0.04[a]	< 0.01	< 0.01
20:3n-3	0.02[a]	0.01[b]	0.01[b]	< 0.01	0.06
20:3n-6	0.16[a]	0.12[a]	0.12[a]	< 0.01	< 0.01
20:4n-6	0.35[a]	0.25[b]	0.24[b]	0.02	< 0.01
20:5n3 EPA	0.04[a]	0.01[b]	0.01[b]	< 0.01	< 0.01
21:0	0.03[b]	0.04[a]	0.04[a]	< 0.01	< 0.01
22:0	0.02	0.02	0.02	< 0.01	0.99
22:1n-9	0.01	0.01	0.01	< 0.01	0.15
22:2	0.01	0.01	0.01	< 0.01	0.40
22:5n3 DPA	0.12[a]	0.07[b]	0.07[b]	< 0.01	< 0.01
22:6n3 DHA	0.012[a]	0.007[b]	0.005[b]	< 0.01	< 0.01
23:0	0.014[a]	0.012[b]	0.012[b]	< 0.01	0.01
24:0	0.020	0.02	0.02	< 0.01	0.26
24:1	0.01	0.01	0.01	< 0.01	0.91
CLA cis-9, trans-11	0.47	0.47	0.46	0.01	0.69
CLA trans 10, cis-12	0.03[b]	0.06[a]	0.05[a]	< 0.01	< 0.01
CLA cis-9, cis-11	0.024[a]	0.02[ab]	0.01[b]	< 0.01	0.08
CLA trans-9, trans-11	0.13[b]	0.15[a]	0.15[a]	< 0.01	0.01
Total SFA[2]	43.96[b]	46.43[a]	46.49[a]	0.37	< 0.01
Total MUFA[3]	51.71[a]	49.04[b]	49.01[b]	0.38	< 0.01
Total PUFA[4]	4.32	4.52	4.49	0.08	0.17
Total n-6[5]	3.14[b]	3.47[ab]	3.44[a]	0.10	0.07
Total n-3[6]	0.46[a]	0.33[b]	0.32[b]	0.03	0.01
n6-n3 ratio[7]	7.84[a]	10.34[b]	10.90[b]	0.49	< 0.01
Total FA[8]	14.66[b]	17.48[a]	18.26[a]	0.70	< 0.01

[a,b]Least squares means in the same row lacking a common superscript differ ($P < 0.05$).

[1]Greatest standard error of the mean among treatments.

[2]Total SFA = 8:0 + 10:0 + 11:0 + 12:0 + 14:0 + 15:0 + 16:0 + 17:0 + 18:0 + 20:0 + 21:0 + 22:0 + 23:0 + 24:0.

[3]Total MUFA = 14:1 + 15:1 + 16:1 + 18:1 cis-9 + 18:1 cis-11 + 18:1 trans-9 + 18:1 cis-11 + 20:1 + 24:1.

[4]Total PUFA = 18:2n-6 cis + 18:2n-6 trans + 18:3n-6 cis + 18:3n-3 + 20:2 + 20:3n-6 + 20:4n-6 and 22:1n-9 + 20:5n-3 + 22:5n-3 + 22:6n-3 + 22:2 + CLA cis-9, trans-11 + CLA trans-10, cis-12 + CLA trans-9, trans-11 + CLA cis-9, cis-11.

[5]Total n-6 = 18:2n-6 cis + 18:2n-6 trans + 18:3n-6 cis + 20:3n-6 + 20:4n-6.

[6]Total n-3 = 18:3n-3 + 20:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3.

[7]n-6-n-3: (18:2n-6 cis + 18:2n-6 trans + 18:3n-6 cis + 20:3n-6 + 20:4n-6)/(18:3n-3 + 20:3n-3 + 20:5n-3 + 22:5n-3 + 22:6n-3).

[8]Total percent of fatty acid in sample.

Table 6. Pearson correlation coefficients showing relationships between consumer palatability ratings[1] and proximate data[2] in Angus, commodity, and grass-fed ground beef

Item	Overall liking	Tenderness	Juiciness	Flavor liking	Texture liking	Fat	Moisture	Protein
Tenderness	0.68*							
Juiciness	0.70*	0.84**						
Flavor liking	0.77*	0.28	0.26					
Texture liking	0.90**	0.67*	0.74*	0.59				
Fat	0.38	–0.12	0.23	0.30	0.29			
Moisture	–0.26	0.21	–0.28	–0.38	–0.34	–0.99***		
Protein	–0.46	0.07	0.11	–0.68*	–0.18	–0.41	0.39	

*Significant correlation $P < 0.05$.

**Significant correlation $P < 0.01$.

***Significant correlation $P < 0.001$.

[1]Consumer rated each steak on a line scale for tenderness, juiciness, flavor liking, texture liking, and overall liking.

[2]Chemical percentages of fat, moisture, and protein.

effect ($P > 0.05$) on protein content. Similarly, O'Quinn et al. (2016) reported no statistical differences between grain-fed and grass-fed ground beef for protein content.

Fatty acids

Saturated fatty acids. Fatty acid profiles of ground beef from 3 sources are summarized in Table 5. In the current study, the SFA with the greatest proportion in the samples across all treatments were: myristic acid (14:0), palmitic acid (16:0), and stearic acid (18:0). Mean squares indicate that samples of ground beef from the 2 grain-fed treatments had greater ($P < 0.05$) total saturated fatty acids (SFA) than grass-fed samples. Grain-fed ground beef treatments had higher ($P < 0.05$) proportions for 14:0 and 18:0 than grass-fed; however, there were no differences ($P > 0.05$) for 16:0 across all treatments. Many studies reported similar results for 14:0 on *longissimus* steaks (Realini et al., 2004). In addition, Melton et al. (1982a) indicated an increase of 18:0 and a decrease of 16:0 proportion in ground beef from grass-fed cattle compared with grain-fed ground beef. It is noteworthy that depending on the muscles used for ground beef production, the fatty acid profile may vary within a beef carcass (Alfaia et al., 2007).

Monounsaturated fatty acids. It is well documented that *longissimus* steaks grain-finished cattle contain a greater amount of total monounsaturated fatty acids (MUFA; Realini et al., 2004; Duckett et al., 2013). However, in the current study, ground beef from grass-fed cattle had higher MUFA ($P < 0.01$) than the grain-fed treatments. O'Quinn et al. (2016) found strip steaks from grain-finished cattle contained similar total MUFA than organic grass-fed beef. Additionally, oleic acid (18:1 cis-9) and palmitoleic acid (16:1) represented the 2 major MUFA in samples across all treatments and were found in higher ($P < 0.01$) proportion in grass-fed ground beef than the grain-fed treatments. Enser et al. (1998) reported oleic acid increased in 4 different muscles from grass-fed cattle compared to grain-fed. The higher proportion of MUFA in samples from grass-fed than grain-fed ground beef may be due to various reasons: (1) In the United States, approximately 283 million pounds of meat from cull beef and dairy cows were produced in 2015, yet only 20% was labeled as grass-fed beef, leaving 227 million pounds of domestic unlabeled grass-fed trim in the market. Grass-fed trim could be affecting the fatty acid profile of samples (Cheung and McMahon, 2017). (2) Seasonality plays a key role in fatty acid deposition in cattle, and since the grass-fed ground beef chubs were frozen, animals may have been harvested at different times. Alfaia et al. (2007) reported higher relative proportions for MUFA in *longissimus* muscle from cattle harvested in spring than autumn.

Polyunsaturated fatty acids. Total PUFA was similar ($P > 0.05$) across all treatments. Linoleic acid (18:2n-6 *cis*), an essential FA in human nutrition, cannot be synthesized by humans (Daley et al., 2010) and it is found in all beef, but typically higher in grass-fed beef (Realini et al., 2004). However, in this experiment, ground beef from grain-fed treatments contained a higher ($P < 0.05$) proportion for 18:2n-6 *cis* than grass-fed ground beef. Additionally, some authors reported no significant differences between concentrate (grain) and forage (grass) treatments for 18:2n-6 (Alfaia et al., 2009; Duckett et al., 2013). EPA (20:5n3) and DHA (22:6n3) were higher ($P < 0.01$) in grass-fed beef than commodity and Angus beef. As expected, omega-3 polyunsaturated fatty acids (n-3 PUFA) were found in the greatest ($P < 0.05$) proportions in samples of grass-fed beef. The omega-6: omega-3 ratio for grass-fed ground beef was lower

Table 7. Pearson correlation coefficients showing relationships between fatty acids[1] and consumer palatability ratings[2] in Angus, commodity, and grass-fed ground beef

Fatty acid	Tenderness	Juiciness	Flavor liking	Texture liking	Overall liking
8:0	0.04	0.33*	–0.13	0.44**	0.51***
10:0	–0.10	0.34*	–0.25	0.43**	0.46**
12:0	0.17	0.35*	–0.24	0.45**	0.46**
14:0	0.05	0.32*	–0.26	0.45**	0.46**
14:1	–0.02	–0.34*	0.26	–0.45**	–0.47**
15:0	0.38*	–0.26	0.29	–0.45**	–0.44**
15:1	0.37*	–0.31*	0.27	–0.44**	–0.44**
16:0	–0.21	0.32*	–0.26	0.45**	0.45**
16:1	0.01	–0.33*	0.26	–0.45**	–0.46**
17:0	0.42*	–0.28	0.28	–0.44**	–0.44**
18:0	–0.01	0.34*	–0.27	0.47**	0.46**
18:1 trans-9	0.50**	–0.33*	0.25	–0.44**	–0.46**
18:1 trans-11	0.07	0.34*	–0.22	0.43**	0.44**
18:1 cis-9	–0.17	0.31*	–0.26	0.43**	0.46**
18:1 cis-11	0.19	–0.32*	0.26	–0.44**	–0.46**
18:2n-6 cis	0.31	0.35*	–0.24	0.45**	0.47**
18:2n-6 trans	0.39*	–0.31*	0.27	–0.44**	–0.45**
18:3n-3	0.07	0.29	–0.25	0.41**	0.45**
18:3n-6 cis	–0.24	–0.34*	0.22	–0.45**	–0.47**
20:0	–0.01	–0.35*	0.24	–0.41**	–0.46**
20:1	0.10	–0.06	0.06	–0.24	–0.11
20:2	0.12	–0.32*	0.24	–0.45**	–0.45**
20:3n-3	–0.13	–0.34*	0.25	–0.41**	–0.46**
20:3n-6	0.20	0.35*	–0.22	0.43**	0.48**
20:4n-6	0.34	0.39*	–0.15	0.41**	0.51***
20:5n3 EPA	0.19	0.36*	–0.16	0.23	0.45**
21:0	0.52**	0.43**	0.01	0.31*	0.49**
22:0	0.22	–0.18	0.22	–0.29	–0.28
22:1n-9	–0.04	–0.18	0.24	–0.39**	–0.20
22:2	0.01	–0.23	0.28	–0.36*	–0.36*
22:5n3 DPA	0.32	0.38*	–0.16	0.37*	0.52***
22:6n3 DHA	0.17	–0.23	0.26	–0.41**	–0.36*
23:0	0.35	–0.29	0.28	–0.38*	–0.42**
24:0	0.28	–0.01	0.23	–0.29	–0.12
24:1	0.21	–0.12	0.36*	–0.41**	–0.28
CLA cis-9, trans-11	0.34	0.34*	–0.17	0.46**	0.54***
CLA trans 10, cis-12	0.48**	–0.30*	0.24	–0.43**	–0.43**
CLA cis-9, cis-11	0.13	–0.32*	0.25	–0.45**	–0.38*
CLA trans-9, trans-11	0.43*	0.36*	–0.21	0.45**	0.50***
Total SFA	–0.01	0.32*	–0.27	0.46**	0.45**
Total MUFA	–0.05	0.20	–0.23	0.28	0.38*
Total PUFA	0.41*	–0.32*	0.26	–0.44**	–0.45**
Total n-6	0.33	0.36*	–0.23	0.44**	0.48**
Total n-3	0.18	0.31*	–0.23	0.39*	0.47**
n6-n3 ratio	0.03	0.36*	–0.24	0.50***	0.45**
Total FA[3]	–0.31	–0.27	0.26	–0.40**	–0.43**

*Significant correlation $P < 0.05$.

**Significant correlation $P < 0.01$.

***Significant correlation $P < 0.001$.

[1]Chemical percentages of fatty acids based on total fatty acids.

[2]Consumer rated each steak on a continuous line scale for tenderness, juiciness, flavor liking, texture liking, and overall liking.

[3]Total percent of fatty acid in sample.

($P < 0.05$) than grain-fed source; however, the values from all treatments, exceeded the recommended ratio (4:1) to help decrease unfavorable health conditions (Simopoulos, 2002). Overall, the variation in the fatty acid profile from this study may be due to the lack of feeding regimen control, variation of seasonality, variation between muscles, inclusion of cull cow trim and external fat, and labeling restrictions.

Correlations

Pearson correlations between proximate data and consumer palatability ratings are shown in Table 6. Moisture content was negatively correlated with fat content ($r = 0.99$; $P < 0.01$). This response has been previously reported when comparing moisture and fat content in various beef muscles (Legako et al., 2015). A correlation between consumer palatability ratings and fat content was not found ($P > 0.05$). Thus, in our study, fat content alone did not drive the observed consumer responses. Rather, different fatty acid composition due to the finishing diet may have led consumers to prefer grain-fed over grass-fed beef. Overall liking was positively correlated with juiciness, tenderness, flavor liking, and texture liking ($P < 0.05$). This can be expected and occurred potentially due to the limited ability of consumers to discern between palatability attributes. Several SFA (8:0, 10:0, 14:0, 16:0, 18:0, and total SFA) were correlated ($r > 0.43$) with texture and overall liking ($P < 0.01$; Table 7). Furthermore, overall liking was correlated ($r > 0.38$) with MUFA (18:1 trans-11, 18:1 cis-9, and total MUFA; $P < 0.05$). In the current study, oleic acid (18:1 cis-9) represented more than one-third of the total fatty acid content of ground beef across all treatments and is known to have the most beneficial effect on beef flavor desirability (Dryden and Marchello, 1970; Westerling and Hedrick, 1979). Texture liking and overall liking were negatively correlated (r– 0.36) with PUFA (18:2n-6 trans, 18:3n-6 *cis*, 20:2, 20:3n-3, 22:2, 22:6n-3, CLA trans 10, cis-12, CLA cis-9, cis-11, and total PUFA; $P < 0.05$). These findings are in line with other studies, where PUFAs in ground beef has been identified to be less desirable (Hunt et al., 2016; O'Quinn et al., 2016). In the present study, several PUFA were shown to be negatively correlated with overall liking. Baublits et al. (2009) reported that a higher proportion of PUFA may negatively affect beef fat sensory characteristics. In previous studies, it has been demonstrated that beef from grass-fed cattle has a higher proportion of omega-3 fatty acids in comparison with beef from grain-fed cattle (Daley et al., 2010). As a result of this increase in omega-3, ground beef from grass-fed cattle has been described as "grassy" and "fishy" (Melton et al., 1982b)

Conclusion

Consumers preferred Angus and commodity beef over grass-fed beef. Different fatty acid composition can play a determinant factor in palatability and can affect consumer eating experience. The proportion of PUFA from commodity and Angus ground beef and grass-fed ground beef was similar in this study. Individual PUFA, including EPA (20:5n3) and DHA (22:6n3) were in greater proportion in grass-fed than grain-fed ground beef. Grass-fed labels can influence purchasing decision of ground beef and it was observed that 80% of panelists, who participated in this study, were willing to spend extra ($0.86 ± $0.49) to purchase omega-3 rich ground beef products.

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