Project Title: Characterizing Quality and Composition of Beef Derived from Cattle Fed Finishing Diets With or Without Distiller's Grains

Principle Investigator(s): J. Drouillard, Ph.D., M. Dikeman, Ph.D., C. Reinhardt, Ph.D.

Institution(s): Kansas State University

Completion Date: May 2008

Background

Rapid expansion of fuel ethanol production has made available abundant supplies of distiller's grains with solubles, which are well-suited as a substitute for cereal grains in finishing cattle diets. Several recently reported experiments have revealed that feeding distiller's grains may have adverse effects on carcass value as a result of the tendency to produce carcasses with lower quality grades and(or) higher yield grades. The effects on quality grade have been most evident in flaked grain diets, but effects on yield grade are more-or-less independent of the type of grain that is fed. This may be a result of substituting starch as an energy source with non-starch carbohydrates, fats, and proteins when cereal grains are replaced by distiller's grains. Researchers at Texas A&M University have proposed that the accumulation of intramuscular fat (i.e., marbling) may be influenced by the presence of energy substrates that yield glucose, as it appears that glucose may be the preferred energy source for the fat-producing cells that are located in this region of the muscle tissue. Starch is the primary energy substrate in grain, and when it is digested in the intestine it yields large quantities of glucose. This is not the case when distiller's grains are substituted for starch-based feeds.

The manner in which grains are processed before feeding also has a significant impact on the proportion of starch that is converted to glucose. It is well-documented that steam flaking results in extensive digestion of starch within the rumen compared to dry rolling. Dry-rolled corn is less extensively digested in the rumen, thus allowing for increased starch supply to the intestine. This increases glucose absorption from the small intestine, which is believed to be directly tied to the synthesis of intramuscular fat. It is conceivable that partial substitution of steam-flaked corn with dry-rolled corn would increase glucose supply for intramuscular fat deposition, thus compensating for the reduced digestion in the rumen and improving quality grade when distiller's grains are added to the diet.

Methodology

Yearling heifers (n=689) with an average initial body weight of 668 lbs were blocked by weight and randomly allotted, within block, to each of 28 feedlot pens. Experimental treatments consisting of four different feedlot diets were assigned randomly to pens such that each treatment appeared once within each group of 4 adjacent feedlot pens. Feedlot pens provided 180 ft2 of pen surface area per animal, and were equipped with fence-line feed bunks that provided 12-14 linear inches of bunk space per animal. All cattle were fed a series of step-up diets during the first 15-20 days after arrival in the feedlot (June, 2007). The final finishing diets (Table 1) were fed for the remaining 140 days of the finishing period (through October, 2007). The ingredient compositions of final treatment diets are shown in Table 1. Nearly half of the pens of cattle (12 of 28 pens) were sent to slaughter after 137 days on feed, while all other pens of cattle remained until 157 days on feed.

On the day of harvest, pens were weighed, loaded onto trucks and transported approximately 90 miles to a commercial abattoir in Emporia, Kansas. The incidence and severity of livers abscesses and hot carcass weight were determined on the day of harvest.

Funded by the Beef Checkoff

Following a 24-hour chill, USDA yield grade; USDA quality grade; 12th-rib fat thickness; percentage kidney, pelvic and heart fat; rib-eye area; and marbling were determined for each carcass.

At each slaughter point, 4 cattle were selected at random from each of 12 feedlot pens, and full rib sections (with the rib plate attached) were obtained from the right side of each carcass for subsequent evaluation of sensory attributes, retail display life, and compositional analyses. The ribs were individually identified and transported to the KSU Meats Laboratory for fabrication. Identity of two ribs was lost in transit, so the sensory and compositional analyses were limited to 94 carcasses.

Separation of the rib was performed as described by Hankins and Howe (U.S. Dept. of Agriculture, Technical Bulletin, No. 926, 1946) to yield 9th-10th-11th rib sections. These rib sections were blocked into groups of four, one from each treatment, and then physically separated into lean, fat, and bone. The separated portions were weighed, vacuum packed, and frozen for later chemical analysis. The separated lean and adipose portions were ground twice, then frozen with liquid N2, and pulverized to a powdery consistency to homogenize the sample. These samples were then used to evaluate fatty acid profiles of triglycerides and phospholipids, protein, moisture, ash, and vitamin E concentrations.

The fatty neutral and polar lipids were separated according to the procedures described by Noci et al. (J. Anim. Sci., 2005; 83-1167-1178). Separation and quantification of fatty acid methyl esters in the separated portions was conducted on a flame ionization gas chromatograph (model 5890 series II, Hewlett Packard) fitted with a Supelco 2560 capillary column (100 m x 0.25 mm x 0.20 µfilm). Helium was used as the carrier gas, with a flow rate of 1.1 ml/min, initial temperature of 140◦C, followed by a 4◦C/min temperature increase to reach the final temperature of 240◦C. The final temperature was held for 15 minutes, while the injection and detector temperatures were maintained at 260◦C. The concentrations of fatty acids ranging from C8 to C24 were determined. Also from the pulverized lean and adipose tissue moisture, protein and ash were determined. Protein and moisture fractions were determined by AOAC official methods of analysis. Ash was determined on both portions by methods described by the AOAC official methods of analysis. Samples of the lean separated portion were sent to DSM Nutritional Products for determination of tocopherol (vitamin E) concentrations.

The *Longissimus* muscles were removed from the 6th, 7th, and 8th rib sections, weighed, vacuum packed, and wet aged for two weeks. At the conclusion of the 2-week aging process, the samples were patted dry with absorbent towels and weighed again to evaluate purge loss during storage. From these samples, steaks (1- in thick) were cut from most posterior end and used for the retail display study. Steaks were placed cut side up on 17 S white foam trays with a Dri Loc pad (Dri-Loc, Cryovac Sealed Air Corporation, Duncun, SC) and wrapped with PRV film (MAPAC M [23250 cc/m², 24 hrs, 72 gauge], Bordon Packaging and Industrial Products, North Andover, MA). The steaks were placed in a retail display case with a temperature of 3±1.6◦C for seven days. The display lighting consisted of 1614 ± 53.82 1x (45.72 ± 1.52 m candles) light intensity, 40 W Del Warm White 3000◦K (Phillips Lighting Company, Somerset, NJ). Instrument color was evaluated for CIE L * a * b* values for illuminant A and reflectance from 400 to 700 nm at 10 nm increments using a Hunter Miniscan XE Spectrophotometer (3.18 cm diameter aperture, 10◦ observer; Hunter Associates Laboratory, Reston, VA). On each day of evaluation, readings were taken from three locations on the *Longissimus* muscle, being careful to avoid intramuscular fat depots. Readings were averaged for statistical purposes. Steaks were rotated left to right and front to back twice daily. Once the 7-day display period was completed, the steaks were analyzed for lipid oxidation using a modified TBARS procedure (Witte, 1970). The steaks were chopped, then frozen with liquid N2 and pulverized to a powdery consistency in a Waring blender (Waring Products Division, Hartford, CT). In duplicate, 10 g of the frozen pulverized sample were weighted into mini-Waring

BEEF®
Funded by the Beef Checkoff

blender cups (100 mL capacity). Fifteen mL of 7.2% cold perchloric acid and 20 mL cold distilled de-ionized water were added to precipitate the protein and extract malonaldehyde from the sample. Samples were then blended for 15 s and gravity filtered through Whatman no. 2 filter paper (Whatman International LTD., Maidstone, UK). Five mL 0.02 M thiobarbituric acid reagent solution (1.4415 g TBA and 500 mL de-ionized water) were then added to the filtrate and, mixed. The resulting mixture was stored for 18 to 24 h in complete darkness at room temperature to allow the color reaction to develop, after which absorbance was measured at 530 nm on a spectrometer (Spectronic 21, Bausch & Lomb, Rochester, NY). The resulting values were reported as mg of malonaldehyde/kg of steak.

Steaks (1-inch thick) also were cut to be used for sensory analyses, which were performed by the Sensory Analysis Center in the Department of Foods and Nutrition, Kansas State University, Manhattan, KS. The sensory steaks were evaluated for 10 attributes: initial tenderness; juiciness; chewiness; mealy texture; fiber awareness; residual connective tissue; beef flavor; blood/serumy flavor; metallic flavor, and rancid flavor. Each steak was evaluated by a five-member, professional panel using a 15-point scale graded in increments of 0.5. For flavor profiling, the steaks were thawed and cooked to an internal temperature of 160 ◦F on an electric broiler and cut into ½ x ½ x 1 inch samples. The samples were presented along with reference samples. Also, from these same steaks, cooking loss was measured by taking an initial raw weight and then weighing the cooked steak.

Formation of heterocyclic amines was achieved by cooking rib steaks (1-in thick) on a Teflon® covered electric grill with a temperature controller (Toastmaster, Denver, CO) at 400◦F for 5.0 minutes per side. Temperature profile of the grill surface was measured using a surface probe thermometer (Barnant Company, Barrington, IL) prior to the cooking. The steaks were placed in the middle section of the grill each time to ensure they were cooked under similar conditions and temperature. The internal temperature profile of the steaks was monitored using a thermocouple thermometer (Barnant Company, Barrington, IL). After cooking, the steaks were chilled in the refrigerator and 2 mm of the surface was sliced off with a commercial grade meat slicer. The surface material was then ground and used for extraction of heterocyclic amines (HCA). The ground samples were stored frozen (-18◦C) if not assayed immediately. Three grams of the previously ground samples were homogenized in 12 ml of 1 M sodium hydroxide and mixed thoroughly with Extrelut refill material and loaded onto an empty Extrelut column. Bond elut PRS tubes were coupled to the Extrelut column and the HCAs were eluted to PRS with 60 mL ethyl acetate using a Supelco Visiprep SPE vacuum manifold (Sigma Aldrich St. Louis MO). The PRS tubes were preconditioned with 7 mL ethyl acetate. The PRS was dried under a stream of nitrogen and rinsed with 6 mL of 0.1 M HCl, 15 mL of methanol/0.1 M HCl (45:55 v/v) and 2 mL of distilled water. The PRS tubes were then coupled to 100 mg C-18 tubes which had been pre conditioned with 1 mL methanol and 10 mL water. The HCAs were concentrated on the C-18 tubes by passing 20 mL of 0.5 M ammonium acetate (pH 8) through the PRS tubes. The C-18 tubes were then rinsed with 2 mL of distilled water and dried under a stream of nitrogen. The HCAs were eluted from the C-18 tubes into 4 mL vials with 1 mL of methanol/ammonium hydroxide (9:1, v/v), concentrated until dry, and dissolved in 25 µL of methanol. The flow rate was 1 mL/min throughout the extraction. The Extrelut columns and refill material were obtained from VWR (West Chester, PA) and the PRS and C-18 tubes from Varian Inc (Palo Alto CA). The final extract (25 µL) was analyzed on HP1090A, series II HPLC (Agilent Technologies, Palo Alto, CA) coupled with a photodiode array UV-visible detector (HP 1040) and an HP 1046A programmable fluorescence detector. The column used was TSK gel ODS-80 TM column (25 cm x 4.6 mm x 5 µm, Tosohass, Montgomeryville, PA) with a mobile phase of 0.01 M triethylamine pH 3.6 (A) and acetonitrile (B). The HCAs were separated using a linear gradient starting with 95% A, 5% B, change to 75% A, 25% B in 30 min, flow rate of 1 mL/min at a column temperature of 40°C. After 30 min, the mobile phase returned to its original ratio (95% A, 5% B) for 10 min to allow the column to re-equilibrate before the next

BEEF®
Funded by the Beef Checkoff

injection. The UV detector was set at 252 nm for IQx, and MeIQx, while the fluorescence detector was programmed accordingly to the excitation/emission wavelengths of 229 and 437 for PhIP. The HCA were confirmed by comparing the retention times and the UV absorbance spectrum of each peak with retention times and library spectra acquired from standard solutions.

Statistical Analysis
Data were analyzed using the Mixed Procedure of the Statistical Analysis System (Version 9.1, Cary, NC) with the fixed effects of weight block, DDGS, DRC, and the interaction between DRC and DDGS.

Findings

Feedlot Performance and Carcass Characteristics
Performance and carcass quality data are shown in Table 2. The two weight blocks of heifers were fed for 137 and 157 days, respectively. We found that average daily gain, feed intake, and feed conversion efficiency were similar among treatment groups ($P > 0.10$). Likewise, there were no differences among treatments with respect to quality grade, yield grade, 12th rib fat thickness, KPH, incidence of liver abscess, or total carcass value. There was a tendency for cattle fed DRC to produce heavier carcasses (721 vs 728 lb for 0 and 25% DRC, respectively; $P < 0.12$). Likewise, cattle fed dry-rolled corn had larger rib-eye size ($P < 0.10$) compared to their counterparts without DRC. Total monetary value of carcasses was not different among treatments ($P > 0.30$), though values were numerically lower for cattle fed distiller's grains.

Carcass Composition
In addition to routine carcass measurements, we evaluated carcass composition, sensory attributes, storage characteristics, lipid peroxidation, fatty acids profiles, and vitamin E concentrations of tissues using a subset of 94 animals. Composition of the 94 carcasses used in this portion of the experiment are shown in Table 3. The attributes of carcasses selected for compositional assays closely reflect those of the larger population.

Physically separated components of the 9th-10th-11th rib sections are summarized in Table 4. We evaluated both the actual separated components of the rib section, as well as the carcass percentages of various components that were predicted using the regression equation of Hankins and Howe (1946). Overall carcass fat was approximately 28.5% when averaged across treatments. There were no differences among treatments with respect to separable portions of lean, fat, and bone ($P > 0.10$). The percentages of protein, moisture, and ether extract also were similar among diets. Using the equations of Hankins and Howe (U.S. Dept. of Agriculture, Technical Bulletin, No. 926, 1946), we found that the percentages of lean, bone, and adipose tissue of the total carcass were not different among treatments.

Sensory Attributes
Longissimus steaks from the 6th, 7th and 8th rib sections were wet aged for two weeks and then used for sensory analyses by a trained panel. We found no differences among treatments in terms of initial tenderness, juiciness, fiber awareness, residual connective tissue, bloody/serumy flavor, or rancid flavor. Overall, we found that steaks from cattle fed DDGS were not noticeably different from those derived from cattle fed diets without DDGS ($P > 0.10$). We did observe that DRC tended to influence several sensory attributes, but the magnitude of these differences is likely not of practical importance.

Retail Display Life and Lipid Oxidation
Longissimus steaks representing the different dietary treatments yielded comparable color changes throughout a 7-day simulated retail display period (Figures 1, 2, 3, and 4). There were no significant interactions between levels of DRC and DDGS ($P > 0.01$), and steaks

BEEF®
Funded by the Beef Checkoff

derived from cattle fed diets with 0 and 25% DRC did not differ with respect to L*, a*, b*, or saturation indices ($P > 0.10$). Likewise, steaks from cattle fed 0 and 25% DDGS underwent comparable changes in color over the 7-day display period ($P > 0.10$). Likewise, there were no interactions between DRC and DDGS for TBARS values. TBARS tended ($P = 0.11$) to be greater when DDGS were included in the diet, but the magnitude of these differences apparently was not sufficient to cause detectable differences in rancid flavors or to induce changes in shelf stability (color change) of beef.

Loss of Weight During Storage (Purge Loss) and During Cooking
We found that there were no differences among treatments with respect to purge loss ($P > 0.10$) during the 14-day wet aging period (Figure 6). However, we did observe that the addition of DRC to finishing diets (Figure 7) increased weight loss during cooking ($P < 0.05$), though these differences were quite modest. Purge loss and shrink during cooking were unaffected by the use of distiller's grains in the diet ($P > 0.15$).

Vitamin E Concentration
Vitamin E was evaluated on the lean portion of the separated 9th-10th-11th rib section, and results are summarized in Figure 8. Diet had no effect ($P > 0.20$) on vitamin E content of lean tissue. This observation is supported by the fact that there were no differences in retail display life among the four dietary treatments.

Fatty Acid Analyses
Fatty acid analyses are summarized for the triglyceride and phospholipid fractions of the fat and lean fractions of the 9th-10th-11th rib section in Tables 6, 7, 8, and 9. There were no interactions between DRC and DDGS with respect to triglycerides extracted from the separable fat portions of the rib ($P > 0.05$), except for C21:0 ($P < 0.01$). Similarly, there were few interactions between DRC and DDGS in terms of changes in fatty acid profiles of neutral lipids (i.e., triglycerides). Notable exceptions include C14:1 and C23:0 in the fat that was extracted from the separated lean fraction (presumably this was largely marbling), which were lower when DDGS were added to diets without DRC, but higher when DDGS were added to diets with DRC. In spite of the statistical significance of these effects, the biological relevance is limited, as the magnitude of change is quite small and they constitute minor fatty acids with no known specific biological activities.

Feeding DRC resulted in small but measureable increases in C12:0, C14:0, and C21:0, and a compensatory decrease in C18:1n9 from triglycerides. The magnitude of these changes was relatively modest. The increase in myristic acid (C14:0) generally is not positive, as this is one of the key fatty acids associated with plaque formation in atherosclerosis. However, the change was relatively small, and was apparent only in fat extracted from the separated lean.

Feeding DDGS resulted in a number of changes in the proportions of fatty acids that appeared in the triglycerides extracted from the separated fat and lean portions of the rib. Generally speaking, the C18:1 fatty acids decreased in response to feeding DDGS, while the proportions of C18:0 and C18:2 increased, including the trans-10, cis-12 isomer of conjugated linoleic acid. The proportion of C16:0 in fat extracted from the separated lean fraction also was significantly decreased, which generally is positive.

Diet had relatively little impact on the proportions of fatty acids within the phospholipid fraction of separated lean and fat. As with the triglycerides, the greatest impact (quantitatively speaking) was in the substitution of C18:2 fatty acids for C18:1 fatty acids in phospholipids.

BEEF®
Funded by the Beef Checkoff

Overall, the changes in fatty acid profiles of steaks derived from cattle fed the different diets were, as expected, quite modest. The distiller's grains used in this experiment were derived entirely from corn, so the fatty acid profiles of the diets should have been similar.

Heterocyclic Amines (HCA) in Steaks
The values for HCA were calculated on a cooked weight basis, and are expressed as a concentration of HCA in parts per billion (Figure 9). They were measured on a ppb and were compared based on the concentration of HCAs present. We found no differences with the addition of DRC or DDGS. With the lipid oxidation values of steaks from cattle fed DDGS having higher values, this posed a possibility of having increased HCA concentrations, however this was found no to be true.

Implications

Based on performance and carcass values in this study, DDGS can effectively substitute for 25% of steam-flaked corn with no deleterious consequences. Substitution of flaked grain with DDGS would therefore be dictated by availability and relative cost of these ingredients. Substitution of flaked corn with dry-rolled corn would reduce overall costs associated with grain processing, which can be achieved while maintaining performance and carcass characteristics that are at least as good as that which can be achieved feeding diets based solely on flaked grain. Additionally, this research indicates that distiller's grains and dry-rolled corn can substitute for flaked corn with no detrimental effects on carcass composition of beef cattle. These data also suggest that DDGS can be added to SFC or DRC diets without impacting the composition of the carcass, especially the fat content. Ultimately, it appears that partial substitution of SFC with DRC and(or) DDGS has little effect on flavor attributes of beef. The absence of differences between diets is positive, indicating that DRC and DDGS can be substituted for SFC with no negative impact on display attributes of fresh meat products. Finally, the research suggests that the industry can feed DDGS without increasing the amount of carcinogenic compounds that are released when cooking beef from cattle fed DDGS.

Table 1. Composition of finishing diets containing steam-flaked corn (SFC) with or without dried corn distiller's grains with solubles (DDGS) and(or) dry-rolled corn (DRC)

	SFC		SFC + 25% DRC	
Ingredient	0%DDGS	25%DDGS	0%DDGS	25%DDGS
SFC	82.1	58.2	56.8	33.1
DDGS	-	25.4	-	25.3
DRC	-	-	25.5	25.3
Alfalfa hay	5.9	5.9	5.9	5.8
Corn steep liquor	6.5	6.4	6.4	6.4
Supplement[1]	5.5	4.1	5.4	4.1

[1]Formulated to meet or exceed nutritional requirements, and provide 300 mg monensin, 90 mg tylosin, and 0.5 mg melengestrol acetate per animal daily. Optaflexx was included at 200 mg/animal for the final 42 days on feed.

BEEF®
Funded by the Beef Checkoff

Table 2. Performance and carcass characteristics of heifers fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS).

	SFC		SFC + 25% DRC			P-values		
Item	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
Final body weight, lb[b]	1138	1132	1146	1146	15.1	0.1154	0.6495	0.6580
Carcass adjusted ADG, lb	3.16	3.12	3.21	3.21	0.05	0.1534	0.6489	0.6724
Dry matter intake, lb/hd/day	18.53	18.85	19.08	19.23	0.38	0.2315	0.5477	0.8299
Adjusted gain:feed	0.171	0.166	0.168	0.167	0.02	0.9055	0.4322	0.5833
Dressed yield, %	62.92	63.64	63.75	64.61	0.4	0.0380	0.0655	0.8715
HCW, lb	723	719	728	728	4.2	0.1154	0.6495	0.6580
USDA Choice or higher, %	43.8	42.0	49.0	39.5	3.8	0.6636	0.1569	0.2699
USDA yield grade	2.69	2.78	2.76	2.67	0.10	0.7917	0.9752	0.1816
Kidney, pelvic & heart fat	2.31	2.30	2.29	2.28	0.02	0.4572	0.6047	0.9704
12th rib thickness, in	0.51	0.53	0.50	0.50	0.02	0.2666	0.4421	0.4470
Marbling score[a]	492	493	499	485	5.83	0.9656	0.2658	0.2212
Liver abscess prevalence, %	2.85	2.85	4.01	2.83	1.35	0.6719	0.6616	0.6588
Longissimus area, in^2	12.72	12.65	12.92	12.88	0.13	0.0909	0.6663	0.9202
Total carcass value, $	935	932	948	935	9.0	0.3303	0.3564	0.5969

[a]500 = small 000

[b]Final body weight was calculated as hot carcass weight divided by a dressed yield of 63.5%.

BEEF®
Funded by the Beef Checkoff

Table 3. Carcass data from cattle selected for evaluation of meat composition and sensory attributes. Cattle were fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS).

	SFC		SFC + 25% DRC			P-values		
Item	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
Final body weight, lb[b]	1141	1164	1170	1135	18	0.9979	0.7518	0.1030
HCW, lb	724	739	743	721	11	0.9979	0.7518	0.1030
USDA Choice or higher, %	56.4	33.3	41.7	56.4	10.5	0.6882	0.6882	0.0713
USDA yield grade	2.65	2.63	2.71	2.65	0.18	0.8161	0.8161	0.9054
Kidney, pelvic & heart fat, %	2.40	2.30	2.26	2.31	0.06	0.2459	0.6393	0.2239
12th rib fat thickness, in	0.49	0.53	0.55	0.49	0.04	0.7777	0.7613	0.2066
Marbling score[a]	544	487	496	500	16.2	0.2749	0.0982	0.0615
Liver abscess prevalence, %	0.00	0.00	4.18	4.35	3.06	0.1630	0.9762	0.9757
Longissimus area, in^2	12.78	12.80	13.10	12.71	0.38	0.7602	0.6180	0.5846
Total carcass value, $	964	968	965	934	18.2	0.3665	0.4410	0.3250

[a]500 = Small 0

[b]Final body weight was calculated as hot carcass weight divided by a dressed yield of 63.5%.

Funded by the Beef Checkoff

Table 4. 9th-10th-11th rib separation values, actual and calculated from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS).

	SFC		SFC + 25% DRC			P-values		
Item	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
Separated bone, % of the 9th-10th-11th rib section	19.0	21.3	19.6	19.6	0.70	0.4366	0.1080	0.1044
Separated lean, % of the 9th-10th-11th rib section	50.6	48.0	49.8	50.0	1.06	0.5602	0.2327	0.1785
Separated fat, % of the 9th-10th-11th rib section	30.4	30.8	30.6	30.4	1.27	0.9556	0.9168	0.8235
Lean , % of edible portion[a]	62.6	61.1	62.0	62.2	1.40	0.8482	0.6362	0.5619
Fat, % of edible portion[a]	37.4	38.9	38.0	37.8	1.40	0.8482	0.6362	0.5619
Bone, % of dressed carcass	15.3	16.2	15.5	15.5	0.31	0.4366	0.1080	0.1044
Lean, % of dressed carcass	56.1	54.0	55.4	55.6	0.84	0.5602	0.2327	0.1785
Fat, % of dressed carcass	28.4	28.7	28.5	28.4	1.06	0.9556	0.9168	0.8235
Protein, % of edible portion[a]	15.8	16.0	15.9	16.0	0.25	0.7080	0.5598	0.8545
Moisture, % of edible portion[a]	50.4	50.4	50.9	50.4	0.67	0.7379	0.7544	0.6732
Ether Extract, % of edible portion[a]	32.1	31.9	31.4	31.8	0.95	0.6664	0.9018	0.8094
Ash, % of edible portion[a]	0.019	0.019	0.020	0.021	0.001	0.0946	0.8350	0.5817

[a]edible portion is the sum of lean and adipose tissues

BEEF®
Funded by the Beef Checkoff

Table 5. Sensory attributes of *Longissimus* steaks from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS).

	SFC		SFC + 25% DRC			P-values		
Item	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
Initial tenderness	10.26	9.96	9.84	10.15	0.1970	0.5603	0.9819	0.1404
Juiciness	4.66	4.70	4.63	4.93	0.1964	0.6159	0.3942	0.5179
Chewiness	9.10	9.23	9.39	9.27	0.0838	0.0660	0.9673	0.1514
Mealy texture	1.98	2.03	1.87	1.70	0.1268	0.0932	0.6596	0.4108
Fiber awareness	8.77	8.81	8.92	8.85	0.0951	0.3244	0.8591	0.5912
Residual connective tissue	2.37	2.50	2.61	2.48	0.1228	0.3659	0.9778	0.3082
Beef flavor ID[a]	11.40	11.05	10.92	11.14	0.1101	0.0872	0.5904	0.0186
Bloody/serumy	3.89	3.75	3.75	3.90	0.1322	0.9390	0.9639	0.2933
Metallic flavor	1.57	1.66	1.85	1.78	0.1062	0.0795	0.9054	0.4864
Rancid flavor	0.05	0.05	0.08	0.15	0.0475	0.1977	0.4299	0.4833

[a] DRC*DDG interaction $P < 0.05$

BEEF
Funded by the Beef Checkoff

Table 6. Fatty acid concentrations of triglycerides extracted from separated fat fraction of the 9th-10th-11th rib section, reported as percent of total fatty acids from triglyceride in sample.

	SFC		SFC + 25% DRC			P-values		
Fatty acid[a]	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
C6:0	0.0227	0.0225	0.0218	0.0359	0.0067	0.3478	0.2944	0.2838
C8:0	0.109	0.110	0.112	0.104	0.0068	0.7988	0.6190	0.5071
C10:0	0.066	0.075	0.075	0.077	0.0031	0.0956	0.0698	0.2450
C11:0	0.0117	0.0121	0.0124	0.0129	0.0006	0.2700	0.5130	0.9228
C12:0	0.087	0.095	0.095	0.101	0.0040	0.0615	0.0774	0.8056
C14:0	3.70	3.79	3.83	4.03	0.11	0.0774	0.1610	0.6113
C14:1	0.79	0.74	0.79	0.89	0.04	0.0630	0.5332	0.0671
C15:0	0.71	0.69	0.71	0.73	0.03	0.5376	0.8663	0.5070
C16:0	26.75	26.23	26.68	26.65	0.33	0.5929	0.4060	0.4563
C16:1	3.49	3.31	3.52	3.33	0.10	0.8066	0.0646	0.9768
C17:0	2.87	2.69	2.79	2.58	0.11	0.3678	0.0796	0.8551
C18:0[c]	16.40	16.87	16.06	17.00	0.33	0.7479	0.0366	0.4824
C18:1n9t[bc]	0.29	0.37	0.27	0.31	0.02	0.0416	0.0032	0.3258
C18:1n11t	0.60	0.65	0.54	0.57	0.05	0.1976	0.4105	0.8430
C18:1n9c[c]	38.79	37.99	38.97	37.39	0.47	0.6528	0.0121	0.4008
C18:1n11c[c]	1.46	1.36	1.51	1.31	0.03	0.9225	<0.0001	0.1208
C18:2n6t[c]	0.017	0.020	0.016	0.019	0.001	0.4431	0.0052	0.9336
C18:2n6c[c]	2.52	3.53	2.65	3.45	0.18	0.8940	<0.0001	0.5470
C18:3n6	0.0110	0.0118	0.0113	0.0124	0.0009	0.5680	0.2517	0.9946
C18:3n3[c]	0.17	0.20	0.17	0.20	0.007	0.7645	0.0006	0.9209
CLA 9C, 11T	0.150	0.155	0.148	0.157	0.0079	0.9857	0.3758	0.8240
C21:0d	0.0103	0.0098	0.0088	0.0106	0.0004	0.3671	0.1068	0.0043
CLA 10T, 12C[c]	0.050	0.061	0.049	0.057	0.0028	0.4751	0.0008	0.5840
CLA 9C, 11C	0.014	0.015	0.013	0.013	0.0007	0.1175	0.3081	0.2268
CLA 9T, 11T[c]	0.25	0.29	0.25	0.27	0.013	0.5523	0.0349	0.4272
C20:3n6[c]	0.052	0.062	0.057	0.065	0.0042	0.3539	0.0388	0.8770
C22:1n9[b]	0.0043	0.0036	0.0056	0.0054	0.0006	0.0090	0.4756	0.6366
C20:3n3	0.0098	0.0109	0.0098	0.0105	0.0006	0.7237	0.1528	0.7568
C20:4n6	0.024	0.026	0.024	0.026	0.0016	0.9629	0.3907	0.9710
C23:0[b]	0.0038	0.0022	0.0043	0.0041	0.0006	0.0305	0.1078	0.1801
C20:5n3[c]	0.0006	0.0003	0.0012	0	0.0003	0.7074	0.0161	0.1982
C24:1	0.0006	0.0018	0.0008	0.0008	0.0005	0.3900	0.2364	0.2385
C22:5n3	0.019	0.020	0.020	0.019	0.0012	0.9967	0.7956	0.5878
C22:6n3	0.0009	0.0015	0.0007	0.0008	0.0005	0.2747	0.4746	0.5686

[a]Fatty acids are represented as number of carbon atoms:number of carbon double bonds. The "n" in fatty acid notation followed by a number denotes the location of the first C=C double bond, counting from the methyl end of the chain. The notations "c" and "t" characterize the double bond as cis or trans isomeric forms.
[b]Main effect of DRC $P < 0.05$
[c]Main effect of DDG $P < 0.05$
[d]DRC*DDG interaction $P < 0.05$

BEEF
Funded by the Beef Checkoff

Table 7. Fatty acid concentrations of triglycerides extracted from separated lean portion of the 9th-10th-11th rib section, reported as percent of total fatty acids from triglyceride in sample.

	SFC		SFC + 25% DRC			P-values		
Fatty acid[a]	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
C6:0	0.035	0.035	0.035	0.036	0.0024	0.7091	0.8216	0.8355
C8:0	0.112	0.122	0.116	0.127	0.0119	0.6789	0.3699	0.9550
C10:0	0.071	0.078	0.076	0.075	0.0051	0.8510	0.4879	0.3993
C11:0	0.014	0.014	0.015	0.016	0.0007	0.0730	0.3943	0.9157
C12:0[b]	0.093	0.094	0.105	0.109	0.0042	0.0009	0.5798	0.7099
C14:0[b]	3.66	3.64	3.92	4.00	0.10	0.0024	0.7636	0.5996
C14:1[bd]	0.81	0.70	0.82	0.89	0.04	0.0130	0.5614	0.0186
C15:0	0.68	0.65	0.70	0.71	0.03	0.1567	0.8390	0.4139
C16:0[c]	3.78	3.38	3.75	3.59	0.10	0.3750	0.0054	0.2294
C17:0	2.54	2.44	2.50	2.36	0.10	0.5113	0.1881	0.7970
C18:0[c]	15.53	16.72	15.79	16.33	0.36	0.8536	0.0143	0.3428
C18:1n9t[c]	0.32	0.41	0.36	0.42	0.03	0.3602	0.0044	0.6833
C18:1n11t	0.69	0.72	0.62	0.61	0.05	0.0727	0.7407	0.6753
C18:1n9c[bc]	39.20	38.23	38.26	37.37	0.46	0.0423	0.0375	0.9270
C18:1n11c[c]	1.47	1.35	1.47	1.32	0.04	0.6017	<0.0001	0.6909
C18:2n6t[c]	0.018	0.020	0.017	0.020	0.0013	0.7740	0.0363	0.6983
C18:2n6c[c]	2.58	3.37	2.69	3.42	0.18	0.6374	<0.0001	0.8819
C18:3n6	0.013	0.013	0.014	0.015	0.0012	0.1255	0.7901	0.5098
C18:3n3[c]	0.19	0.21	0.20	0.22	0.007	0.2069	0.0017	0.7658
CLA 9C, 11T	0.145	0.144	0.129	0.144	0.0081	0.2644	0.3632	0.2667
C21:0[bcd]	0.009	0.012	0.011	0.012	0.0005	0.0201	0.0020	0.0428
CLA 10T, 12C[c]	0.051	0.053	0.048	0.055	0.0028	0.7205	0.0358	0.4841
CLA 9C, 11C	0.017	0.021	0.016	0.017	0.0019	0.1348	0.3021	0.4850
CLA 9T, 11T	0.27	0.29	0.27	0.29	0.013	0.6291	0.0708	0.9759
C20:3n6	0.054	0.061	0.056	0.061	0.0041	0.8194	0.1380	0.7128
C22:1n9	0.0031	0.0044	0.0026	0.0029	0.00085	0.2184	0.3077	0.5673
C20:3n3	0.010	0.011	0.009	0.008	0.0013	0.1709	0.7803	0.5025
C20:4n6	0.034	0.040	0.033	0.043	0.0049	0.8517	0.0909	0.6548
C23:0[c]	0.0037	0.0025	0.0015	0.0040	0.0007	0.5812	0.3576	0.0106
C20:5n3	0.0009	0.0043	0.0005	0.0023	0.00204	0.5414	0.1897	0.6865
C24:1	0.00060	0.00076	0.00148	0.00003	0.00056	0.8860	0.2332	0.1369
C22:5n3	0.0217	0.0228	0.0246	0.0241	0.0019	0.2364	0.8448	0.6639
C22:6n3	0.00003	0.00159	0	0.00088	0.00065	0.5522	0.0520	0.5792

[a]Fatty acids are represented as number of carbon atoms:number of carbon double bonds. The "n" in fatty acid notation followed by a number denotes the location of the first C=C double bond, counting from the methyl end of the chain. The notations "c" and "t" characterize the double bond as cis or trans isomeric forms.
[b]Main effect of DRC $P < 0.05$
[c]Main effect of DDG $P < 0.05$
[d]DRC*DDG interaction $P < 0.05$

BEEF
Funded by the Beef Checkoff

Table 8. Fatty acid profile of phospholipids extracted from the separated lean portion of the 9th-10th-11th rib section, reported as percent of total tatty acids from phospholipid in sample.

	SFC		SFC + 25% DRC			P-values		
Fatty acid[a]	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
C6:0	0.14	0.23	0.30	0.30	0.09	0.2181	0.5858	0.5866
C8:0	9.77	10.36	9.44	10.14	0.56	0.6172	0.2415	0.9116
C11:0	0.19	0.20	0.17	0.19	0.02	0.5885	0.5611	0.9494
C12:0	0.25	0.33	0.20	0.19	0.06	0.1159	0.5586	0.4132
C14:0	0.27	0.36	0.35	0.35	0.04	0.3805	0.2943	0.3210
C14:1	0	0.011	0	0.006	0.007	0.6721	0.1958	0.6721
C15:0	0.22	0.61	0.23	0.24	0.20	0.3592	0.3094	0.3162
C15:1	0.40	0.37	0.40	0.33	0.08	0.8043	0.4938	0.7870
C16:0	9.81	10.07	9.57	10.56	0.44	0.7611	0.1505	0.4010
C17:0	0.62	0.65	0.62	0.53	0.04	0.0932	0.3940	0.0964
C17:1	0.71	0.54	0.61	0.09	0.23	0.2330	0.1316	0.4260
C18:0	12.60	13.17	13.03	13.21	0.24	0.3105	0.1063	0.4016
C18:1n11t	0.33	0.44	0.43	0.16	0.11	0.3791	0.4399	0.0730
C18:1n9c[b]	12.59	10.35	12.52	10.63	0.63	0.8601	0.0011	0.7794
C18:1n11c[b]	1.36	1.28	1.37	1.20	0.05	0.4766	0.0213	0.4033
C18:2n6c[b]	21.37	23.71	20.75	24.06	0.78	0.8596	0.0004	0.5264
C18:3n6	0.18	0.11	0.16	0.17	0.03	0.4786	0.2737	0.1491
C18:3n3b	0.48	0.37	0.49	0.40	0.04	0.5388	0.0039	0.8297
CLA 9T, 11T[b]	0.06	0.02	0.07	0.02	0.02	0.9378	0.0221	0.5940
C20:3n6[b]	3.46	3.17	3.40	3.24	0.10	0.9347	0.0174	0.5173
C20:4n6	16.02	15.35	16.58	16.06	0.67	0.3307	0.3615	0.9035
C23:0	0.32	0.34	0.32	0.37	0.03	0.6619	0.3238	0.6580
C20:5n3[b]	1.48	1.41	1.63	1.27	0.12	0.9705	0.0853	0.2279
C24:1	0.20	0.16	0.17	0.14	0.03	0.4642	0.2241	0.7796
C22:5n3[b]	4.46	3.93	4.44	3.76	0.24	0.6884	0.0130	0.7513
C22:6n3	0.58	0.57	0.68	0.50	0.05	0.8224	0.0570	0.0870

[a]Fatty acids are represented as number of carbon atoms:number of carbon double bonds. The "n" in fatty acid notation followed by a number denotes the location of the first C=C double bond, counting from the methyl end of the chain. The notations "c" and "t" characterize the double bond as cis or trans isomeric forms.
[b]Main effect of DDG $P < 0.05$

BEEF®
Funded by the Beef Checkoff

Table 9. Fatty acid profile of phospholipids extracted from separated fat portion of the 9th-10th-11th rib section, reported as percent of total fatty acids from phospholipid in sample.

	SFC		SFC + 25% DRC			P-values		
Fatty acid[a]	0%DDGS	25%DDGS	0%DDGS	25%DDGS	SEM	DRC	DDGS	DRC*DDGS
C8:0	41.54	42.60	40.91	41.97	2.25	0.7783	0.6364	0.9999
C11:0	0.95	0.83	0.83	0.89	0.06	0.5454	0.6097	0.0971
C12:0	1.87	2.20	1.76	1.89	0.24	0.3929	0.3277	0.6745
C14:0	1.29	1.42	1.31	1.40	0.14	0.9905	0.4094	0.8954
C15:0	0.41	0.37	0.52	0.50	0.11	0.2689	0.8077	0.9210
C15:1	0.019	0	0.042	0.001	0.023	0.6181	0.1946	0.6387
C16:0	10.08	10.11	10.77	10.61	0.63	0.3435	0.9176	0.8758
C17:0[c]	0.64	0.30	0.84	0.60	0.15	0.0979	0.0490	0.7352
C17:1	0.56	0.23	0.35	0.26	0.11	0.4186	0.0590	0.2522
C18:0	7.97	8.35	8.36	8.66	0.37	0.3410	0.3501	0.9047
C18:1n11t	1.14	1.56	0.85	0.96	0.24	0.0689	0.2773	0.5279
C18:1n9[c]	14.49	14.78	15.59	14.76	0.97	0.5723	0.7761	0.5623
C18:1n11c[c]	2.43	1.10	2.18	0.49	0.67	0.5167	0.0246	0.7804
C18:2n6cc	4.33	5.56	4.67	5.25	0.32	0.9490	0.0054	0.3088
CLA 9T, 11T	0	0.02	0	0.01	0.01	0.8769	0.1634	0.8533
C20:3n6	4.80	4.40	3.79	4.69	0.74	0.6236	0.7291	0.3782
C20:4n6	4.70	3.94	4.67	4.74	0.35	0.2616	0.3263	0.2281
C23:0b	0.47	0.31	0.04	0.09	0.15	0.0354	0.7230	0.4937
C20:5n3	0.06	0	0.06	0.27	0.14	0.3496	0.5880	0.3185
C24:1	0.034	0	0.014	0.001	0.018	0.5890	0.1848	0.5689
C22:5n3	0.33	0.29	0.59	0.27	0.13	0.3512	0.1715	0.2812

[a]Fatty acids are represented as number of carbon atoms:number of carbon double bonds. The "n" in fatty acid notation followed by a number denotes the location of the first C=C double bond, counting from the methyl end of the chain. The notations "c" and "t" characterize the double bond as cis or trans isomeric forms.
[b]Main effect of DRC $P < 0.05$
[c]Main effect of DDG $P < 0.05$

Funded by the Beef Checkoff

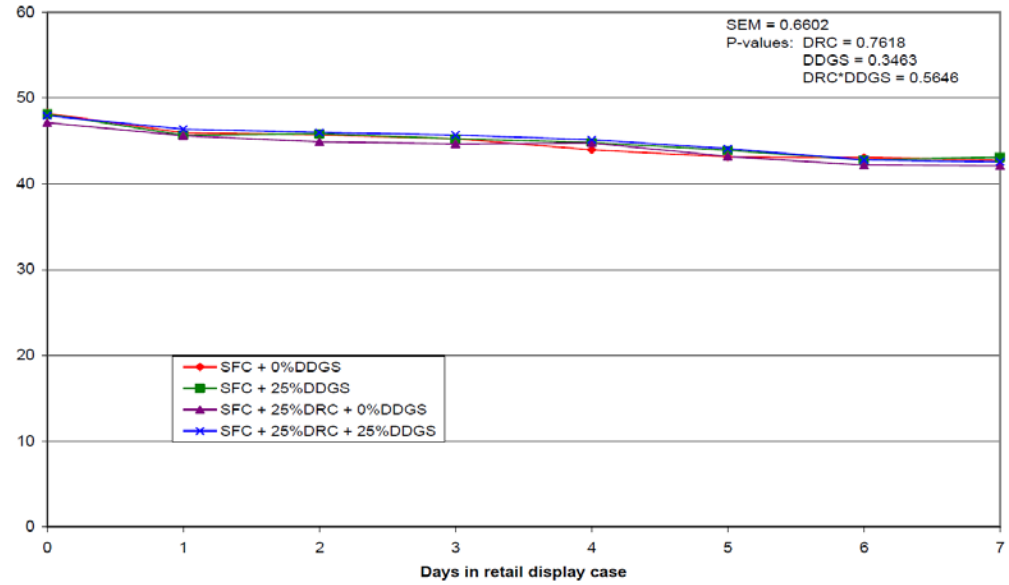

Figure 1. Color change during a 7-day simulated retail display period for steaks from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values indicate L*, or degree of lightness.

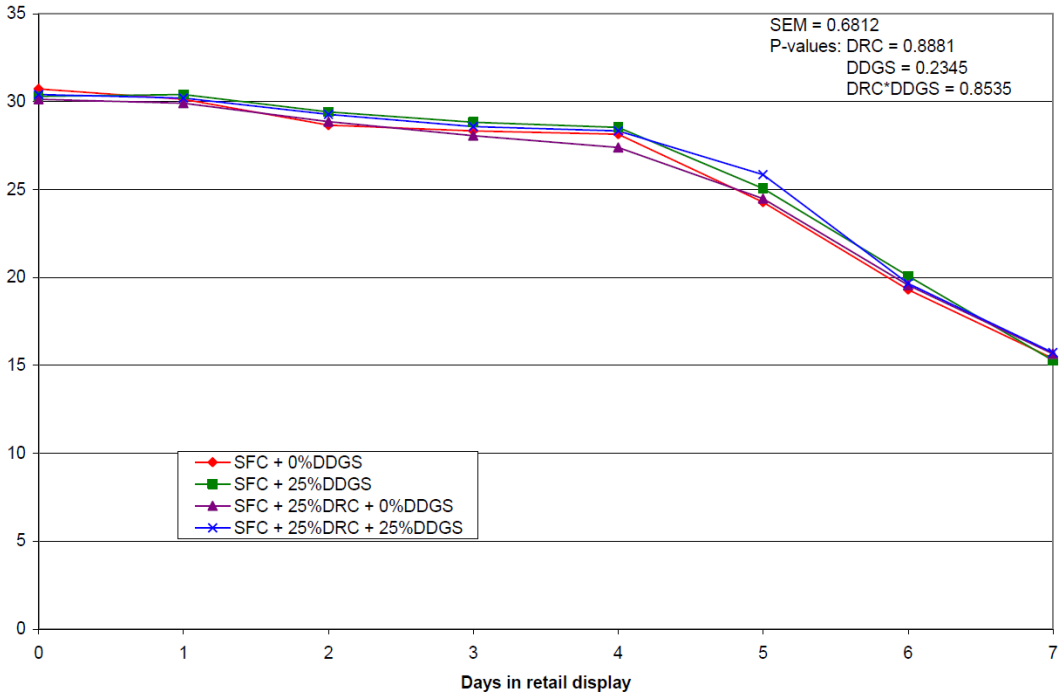

Figure 2. Color change during a 7-day simulated retail display period for steaks from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values are for a*, or redness.

BEEF®
Funded by the Beef Checkoff

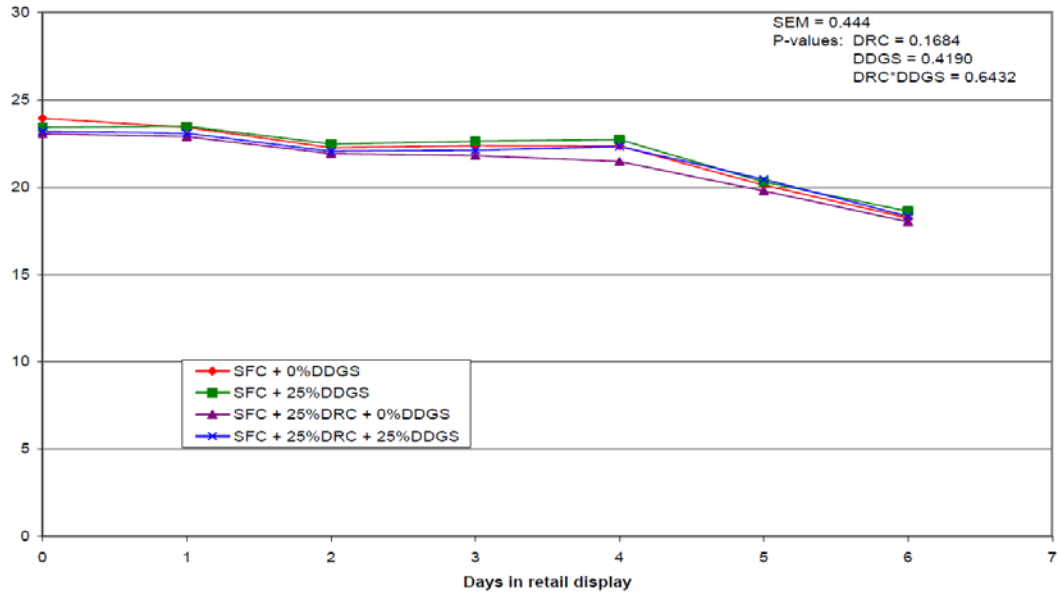

Figure 3. Color change during a 7-day simulated retail display period for steaks derived from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values are for b*.

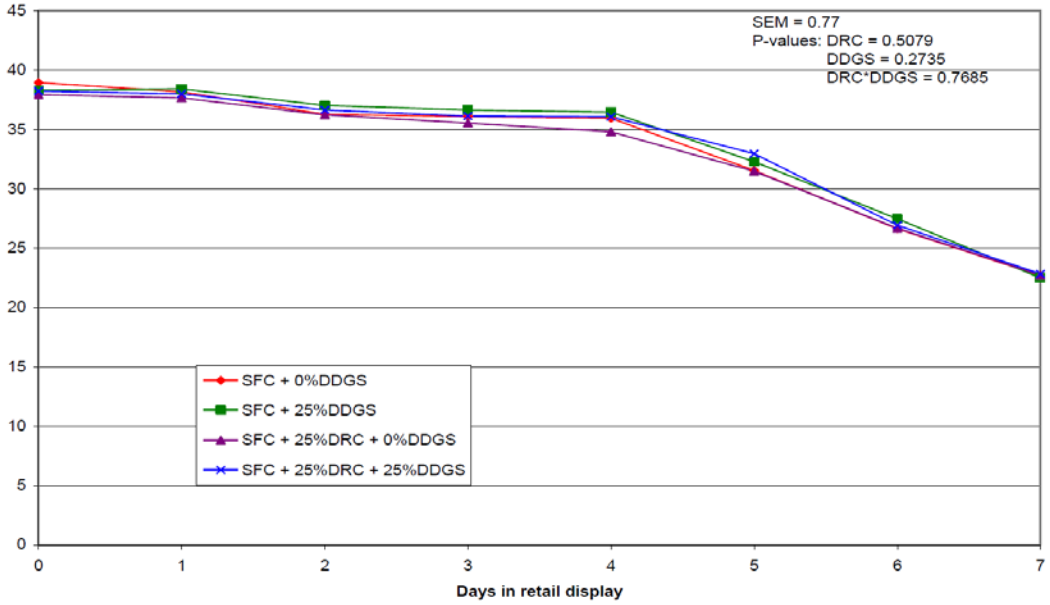

Figure 4. Color change during a 7-day simulated retail display period for steaks derived from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn and 0 or 25% dried distiller's grains with solubles (DDGS). Values are saturation index.

Funded by the Beef Checkoff

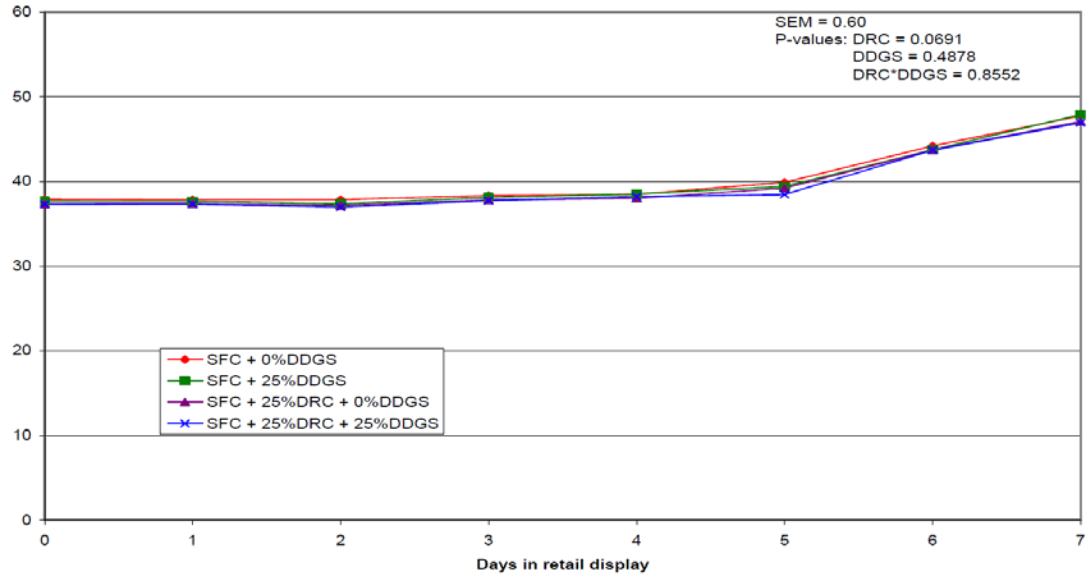

Figure 5. Color change during a 7-day simulated retail display period for steaks derived from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn and 0 or 25% dried distiller's grains with solubles (DDGS). Values are hue angle.

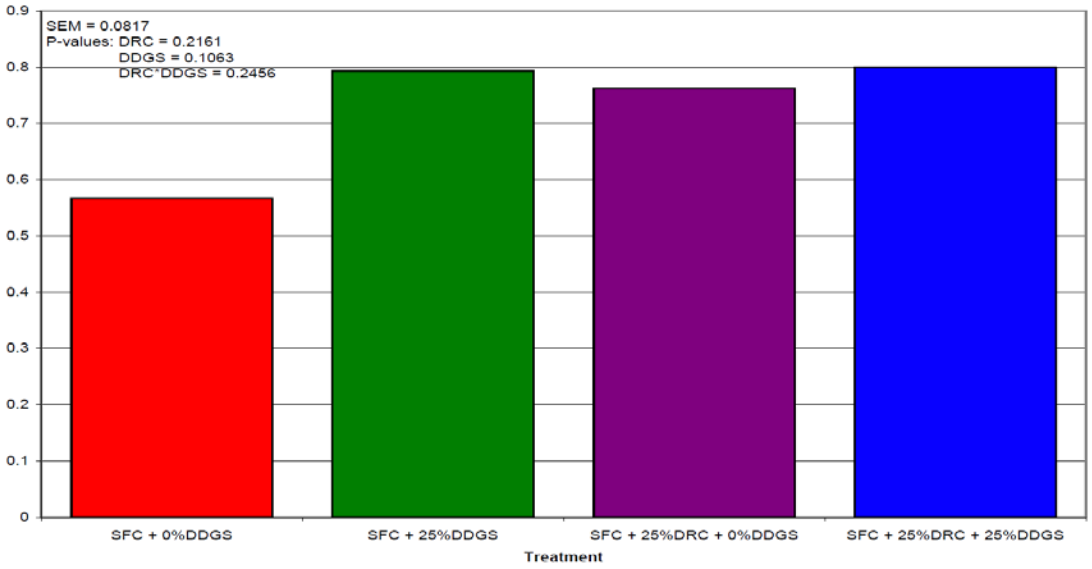

Figure 6. Lipid oxidation (thiobarbituric acid reactive substances; TBARS) in steaks from cattle fed steam-flaked corn (SFC) diets with 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values are mg malonadehyde per gram of wet tissue.

BEEF®
Funded by the Beef Checkoff

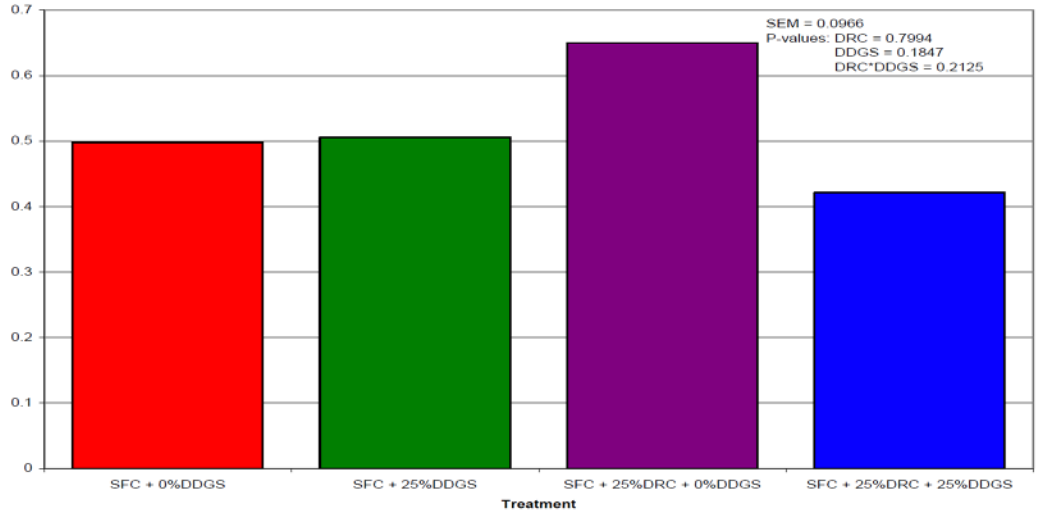

Figure 7. Weight loss during a 2-week storage period (purge) of rib sections from cattle fed steam-flaked corn (SFC) diets with 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values represent weight loss expressed as a percentage of original weight.

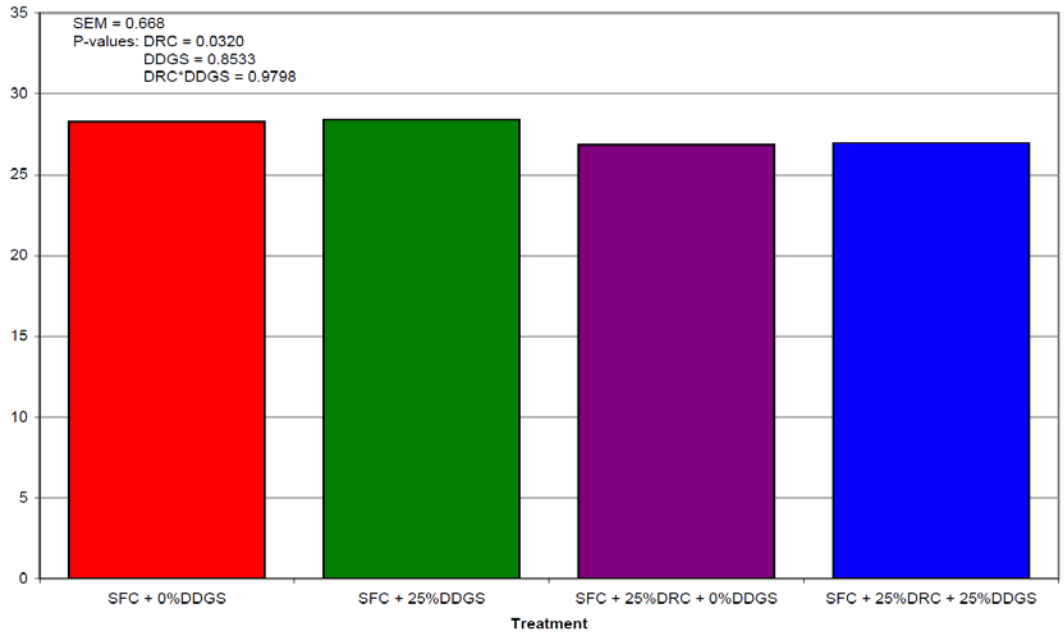

Figure 8. Weight loss during cooking of steaks derived from cattle fed steam-flaked corn diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values represent weight loss expresses as a percent of original weight.

BEEF®
Funded by the Beef Checkoff

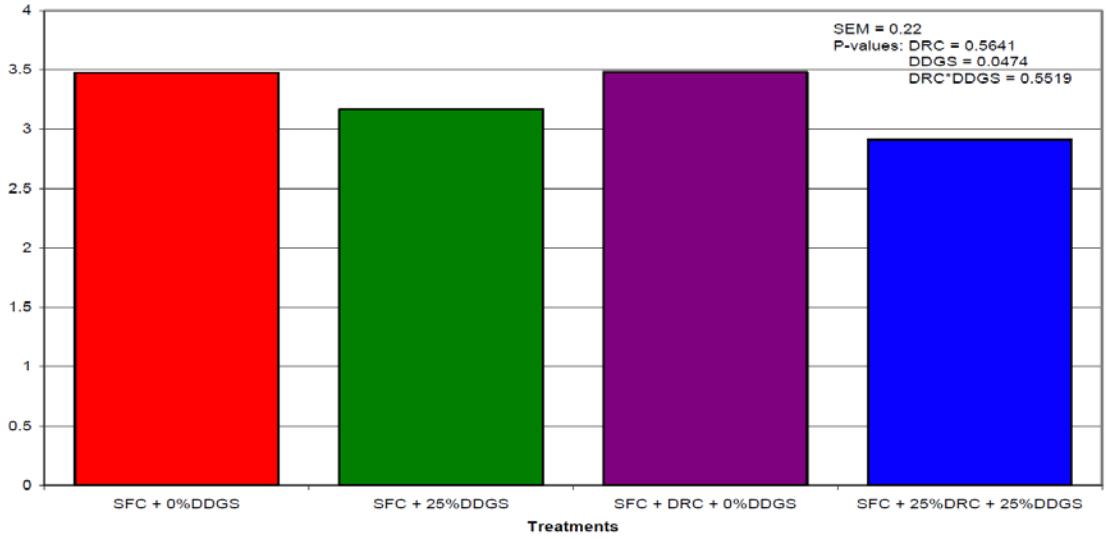

Figure 9. Vitamin E (tocopherol) concentration of steaks derived from cattle fed steam-flaked corn (SFC) diets with 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values indicate parts per million of alpha tocopherol.

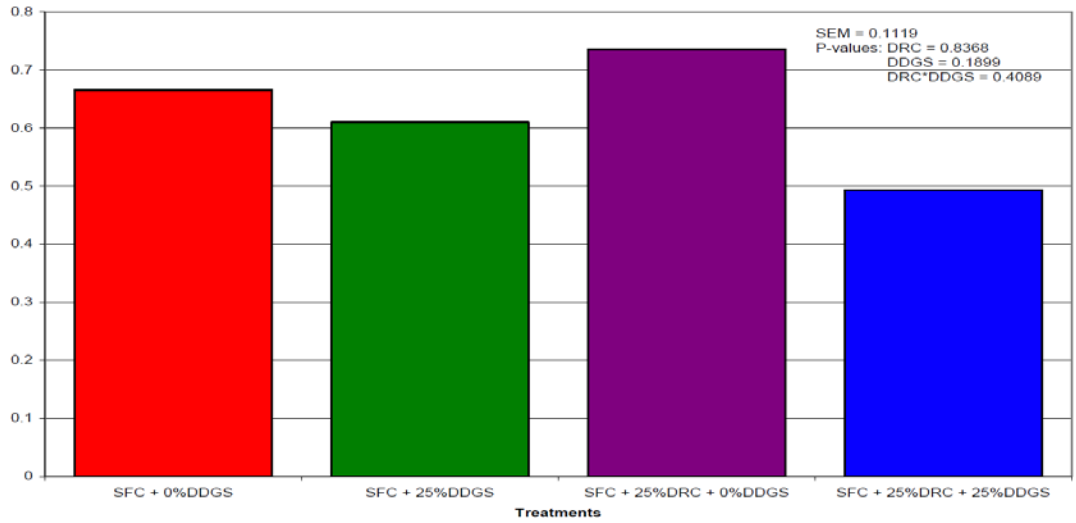

Figure 10. Concentrations of heterocyclic amines (HCAs) in steaks derived from cattle fed steam-flaked corn (SFC) diets containing 0 or 25% dry-rolled corn (DRC) and 0 or 25% dried distiller's grains with solubles (DDGS). Values are parts per billion of heterocyclic amines.

BEEF
Funded by
the Beef Checkoff