Effects of reduced-fat distillers grains inclusion in feedlot diets on cattle growth performance, carcass characteristics and beef quality

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By:

D.M. Paulus Compart*, J.E. Johnston*, G.I. Crawford+, A. DiCostanzo* and R.B. Box*

*Department of Animal Science, University of Minnesota, St. Paul, MN 55108

+Form-A-Feed, Inc., Stewart, MN 55385

Partners:

Minnesota Corn

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ABSTRACT

An experiment was conducted to determine effects of partially replacing dry rolled corn with full- or reduced-fat distillers grains with solubles in feedlot diets on cattle growth performance and carcass characteristics. Nineteen Jersey (initial BW 455 ± 49 kg) and 29 Jersey-Limousin cross steers (initial BW 518 ± 40 kg) were utilized in a generalized randomized complete block design. Steers were individually fed using Calan gates with 4 dietary treatments (dry rolled corn control, C; reduced-fat distillers grains inclusion at 20% of dietary DM with corn oil, FF; reduced-fat distillers grains inclusion at 20% of dietary DM, RFL; or reduced- fat distillers grains inclusion at 47% of dietary DM, RFH). The latter was intended to provide similar dietary fat content as the FF treatment. Cattle were harvested on d 93 at a commercial abattoir and objective carcass measurements as well as USDA Yield and Quality Grades were collected. Strip loins (IMPS #180) and shoulder clods (IMPS #114) were removed from the right side of each carcass 48 h postmortem. Strip loins were evaluated for purge and drip loss and ultimate pH. Strip steaks were used to determine objective (L*, a*, and b*) and subjective color for six consecutive days. Warner-Bratzler shear force (WBSF) was determined from two steaks from each loin. Fresh strip steaks were cooked for consumer sensory evaluation. Ground shoulder clods were used in ground beef objective and subjective color evaluation. Thiobarbituic acid reactive substance assay was evaluated on ground clods day 0 and day 7. The ground beef was then used in further processed production of bologna. Bolonga was evaluated for objective and subjective color. A consumer sensory panel evaluated bologna samples. No differences were observed in cattle consuming full-fat versus reduced-fat distillers grains. Cattle consuming distillers grains (DG) had improved (P < 0.05) BW, ADG, and BW gain relative to cattle not consuming DG. Cattle consuming DG also had improved (P < 0.02) HCW, USDA QG, and percentage of cattle grading USDA Choice and Select. Cattle consuming 20% DG had improved (P < 0.05) USDA YG and percentage of cattle grading USDA Prime. Hot carcass weight (HCW) was greater (P=0.02) in RF-L compared to CON (388.7 vs. 334.7±12.65 kg). Back fat depth was unaffected (P=0.81) by dietary treatment but tended (P=0.06) to be less in Jersey steers (7.36 vs. 9.65±2.79 mm). Ribeye area (REA) was not impacted (P=0.81) by dietary treatment. However, Jersey steers had smaller (P=0.01) REA (83.94 vs 102.26±7.94 cm2). USDA Yield Grade (YG) was not influenced (P=0.73) by dietary treatment, but Jersey steers had lower (P=0.02) YG (2.69 vs. 2.90±0.06). Steers fed CON tended (P=0.09) to have greater WBSF compared to steers fed RF-O (3.00 vs. 2.24±0.20 kg). Steak objective color (L*) was greater (P=0.03) in steers fed RF-Low than steers fed CON (31.23 vs. 27.04±0.95). Consumers rated the liking of the steak flavor higher for samples from the Crossbred cattle (P=0.03) but preferred the texture of Jersey (P<0.001) strip steaks. On the other hand, consumers their overall liking of the bologna samples from Crossbred steers as compared to Jerseys in overall liking, flavor liking, and texture liking (P<0.001, P<0.001, and P=0.02, respectively). In conclusion, Jersey X Limousin Crossbred steers had greater REA and HCW but no differences in the carcass or meat quality attributes evaluated. Feeding reduced-fat distillers grains in replacement of dry-rolled corn did not substantially affect the carcass or meat quality attributes evaluated. Results from this experiment indicate that utilizing reduced-fat DG in place of full-fat DG does not impact animal growth performance or carcass characteristics. Moreover, partially replacing dry rolled corn with DG may lead to an improvement in ADG, HCW, and USDA QG, and a reduction in USDA Select-grading carcasses.

INTRODUCTION

Distillers grains (DG), a coproduct of the ethanol industry, has been utilized in feedlot diets extensively for several years. Recently, ethanol producers have attempted to increase profits by removing oil from corn or DG, thereby creating additional co-products of ethanol production.

Oil can be removed from corn prior to fermentation to ethanol by partial de-germination producing low- fat distillers grains containing 3 to 5% fat (Faulkner et al., 2012). Oil can also be removed from condensed distillers solubles after fermentation of corn to ethanol. This is frequently done via centrifugation (Díaz-Royón et al., 2012). When de-oiled condensed distillers solubles are added to DG, reduced-fat DG with solubles (RFDG) is produced. Generally, RFDG will contain 7 to 9% fat, while traditional full-fat DG product will contain at least 10% fat.

Full-fat distillers grains with solubles have been extensively studied in feedlot diets to determine their effect on rumen fermentation, digestion, growth performance, and carcass characteristics. However, RFDG has not been studied as extensively. With lower fat concentration, there is concern that this may translate to lower energy supply and may impact animal performance. Thus, it was the objective of this experiment to determine the effects of replacing dry rolled corn in feedlot diets with either 20% full-fat or reduced-fat DG or with 47% reduced-fat DG (at isocaloric concentrations with the 20% full-fat DG diet) on cattle growth performance and carcass characteristics.

MATERIALS AND METHODS

All procedures involving animals were approved by the local institutional animal care and use committee. Animals were housed at the Rosemount Research and Outreach Center in Rosemount, MN.

Nineteen purebred Jersey steers (initial BW 455 ± 49 kg) and 29 Jersey-Limousin cross steers (initial BW 518 ± 40 kg) were arranged in a generalized randomized complete block design. Steers were blocked by breed and allotted randomly to 1 of 4 pens.

Steers were individually fed in Calan gates (American Calan, Inc., Northwood, NH) for 93 d. Four dietary treatments were evaluated in this experiment (Table 1 and 2). A dry rolled corn-based diet served as the control treatment (C). The remaining treatments contained various concentrations of reduced-fat distillers dried grains partially replacing dry rolled corn. A single, reduced-fat distillers grains source was used, and where necessary, corn oil was added to the diet at mixing to achieve lipid content of full-fat distillers grains. Distillers grains treatments consisted of reduced-fat distillers dried grains dietary inclusion at 20% with corn oil (RF-O), reduced-fat distillers dried grains dietary inclusion at 20% (RF-L), or reduced-fat distillers dried grains dietary inclusion at 47% (RF-H) of dietary DM. The latter was intended to provide similar dietary fat content as the FF treatment. A vitamin and mineral premix containing monensin was added to all diets; a similar premix containing urea was added to the C diet to meet cattle dietary protein requirements.

Steers were fed dietary treatments once daily at 0900 h. Steers were fed ad libitum and intakes were recorded daily. Feed refusals were removed from feed bunks and weighed daily. Samples of all feed refusals were collected for DM determination. Dietary ingredients were sampled once weekly. All dietary and feed refusal samples were stored at -20°C until laboratory analyses. Dietary ingredients and feed refusal samples were dried in a drying oven (Blue M Electric, Charlotte, NC) at 60°C for 48 h. Ingredient samples were then ground using a 1-mm screen (Thomas Scientific, Swedesboro, NJ). Individual ingredient samples were analyzed for CP, NDF, ADF, ether extract, Ca, P, K, Mg, and S contents by methods 990.03, 2002.04, 973.18, 920.39, and 953.01 (AOAC, 2012), respectively. Metabolizable energy content of the diet was also determined using values obtained from Nutritional Requirements of Beef Cattle (NRC, 1996).

Cattle were implanted with Synovex-S (Zoetis, Florham Park, NJ) on d -28 and were harvested on d 93 at Tyson Inc. (Dakota City, NE). After harvest, carcasses were chilled for 48 h after which carcass characteristics were analyzed. Cattle growth performance and carcass characteristics evaluated included BW, BW gain, ADG, DMI, and gain: feed, HCW, dressing percentage, marbling score, LM area, 12^{th} rib fat thickness, KPH, and USDA YG and QG.

Fresh beef products were fabricated 96 h post-mortem, according to Institutional Meat Purchasing Specifications (IMPS). Strip loins (IMPS #180) and shoulder clods (IMPS #114) were removed 52 h postmortem from the right side of the carcass, and individually identified using carcass identification tags crossbred-referenced to animal identification tags during harvest. Strip loins and shoulder clods were vacuum packaged and maintained at 2° C during transport to the Andrew Boss Laboratory of Meat Science at the University of Minnesota, (St. Paul, MN). All beef products were inspected for vacuum seal, re-packaged if necessary, and shoulder clods were placed in a blast freezer (-20° C) until further evaluation. The strip loins were processed upon return to the University of Minnesota 72H post-mortem.

Strip loins were faced perpendicular to the length of the loin, and steaks were serially cut, 2.54cm thick, from the anterior end of each strip loin. The first steak was designated for drip loss analysis, the second and third were designated for shelf-life analysis. The fourth through seventh steaks were designated for sensory analysis and the eighth and ninth steaks were designated for Warner Bratzler shear force (WBSF) evaluation. A 10g back fat sample was collected from the posterior end of each strip loin before cutting steaks, vacuum packaged, and stored frozen (-20º C) until processing for fatty acid profile analysis.

Shoulder clods, (approximately 9.5 kg each) were thawed (vacuum packaged) at 4° C for 3 d. Entire, untrimmed shoulder clods were ground twice (Cabela's Electric Meat Grinder, Model: 32, Kearney, NE) with a 0.375 cm plate.

Two steaks were placed on polystyrene trays with polyvinylchloride (PVC) overwrap (oxygen transmission rate 1400 cc/m2) and stored at 4º C under cool white fluorescent lighting (Sylvania H968, 100w, 2, 640 LUX) for seven days. Objective color values (CIE, L*, a*, and b*) were taken at six locations on each steak (Hunter Lab Miniscan EZ model 4500S, Reston, VA).

For ground beef retail display, one 225g (±5g) patty per clod was placed on a polystyrene tray with polyvinylchloride (PVC) overwrap (oxygen transmission rate 1400 cc/m2) and stored at 4º C under cool white fluorescent lighting (Sylvania H968, 100w, 2, 640 LUX) for seven days. Objective color values (CIE, L*, a*, and b*) were taken at six locations on each patty with a Hunter Lab Miniscan EZ (model 4500S, Reston, VA).

Subjective color scores (lean color, surface discoloration, and overall appearance) were evaluated by an eight-person trained panel for seven days for both steaks and ground patties. Lean color was evaluated on a 1 to 8 scale with 1 = extremely brown and 8 = extremely bright, cherry red. Surface discoloration was evaluated on 1 to 11 scale with 1 = 91-100% discoloration and 11 = 0% discoloration. Overall appearance was evaluated on a 1 to 8 scale with 1 = extremely undesirable and 8 = extremely desirable (AMSA, 1991).

Drip loss was evaluated for each steak (approximately 158 g) by suspending steak samples for 24 h at 4° C in a sealed Ziploc® bag wrapped loosely. Percent drip loss was calculated as the difference between the initial (product and moisture minus the dried bag) and final weight (unpacked and patted dry) divided by the initial weight multiplied by 100. Vacuum-packaged purge loss of the strip loin and shoulder clod was measured after transport and before further fabrication. Purge loss was calculated as the difference between the initial and final weight divided by the initial weight multiplied by 100.

Duplicate steaks were thawed for 24 h at 4° C, individually wrapped in aluminum foil, and cooked at 180ºC, using a George Foreman Indoor/Outdoor Grill (Model: GGR62. Lake Forest, IL) to an internal temperature of 71° C as indicated by a probe placed at the geometric center of the steaks (Type T thermocouple, Omega Engineering, Stanford, OH). Steaks were stored refrigerated (2º C), equilibrated to room temperature (25º C), and six, 1.27-cm diameter cores were removed from each steak parallel to the muscle fiber by a hand corer. Each core was sheared on a texture analyzer fitted with a Warner-Bratzler shear force attachment (Shimatzu Texture Analyzer, Model: EZ-SX, Kyoto, Japan). Six cores were sheared per steak to represent the entire surface of the longissimus dorsi muscle.

Procedures utilizing human subjects for consumer panel evaluation of sensory attributes were approved by the University of Minnesota Institutional Review Board. The University of Minnesota Food Science and Nutrition Sensory Center recruited eighty-nine untrained consumer panelists for sensory evaluation of fresh strip steaks. All panelists were 18 years of age or older, had no food allergies, and consumed steak at least twice per month. Panelists were paid $5 for their time. Sensory evaluation was conducted by the University of Minnesota Food Science and Nutrition Sensory Center following the research guidelines for sensory evaluation (AMSA, 1995).

Steaks were thawed for 36 h at 4° C, individually wrapped in aluminum foil, cooked at 180° C (General Electric® Range, JASO2 ; Fairfield, CT), to an internal temperature of 71° C as indicated by a probe place at the geometric center of the steak (Pyrex Professional Acu rite Thermometer; Racine, WI). Steaks were cut into 1-cm x 1-cm x 2.54 cm cubes and placed in the top portion of double boilers containing water in the bottom portion heated to ~82° C (replaced every h) to keep samples warm. Each panelist received two pieces of steak per sample (approximately 38° C) in lidded 60 ml plastic soufflé cups coded with random 3-digit numbers. To maintain sample serving temperature, the cups were nested in heated sand (~60° C) contained in round, aluminum pans. Samples were served to subjects balanced for order and carryover effects. Subjects were asked to taste one piece of the sample and rate it for overall liking, liking of flavor, liking of texture, and off flavor intensity. Subjects were then instructed to taste the second piece and rate the intensity of toughness and juiciness. Liking ratings were made on 120-point labeled affective magnitude scales, with the left most end labeled strongest dislike imaginable and the right most end labeled strongest like imaginable. Intensity ratings were made on 20-point line scales with the left most ends labeled none and the right most ends labeled extremely intense for off flavor, extremely tough for toughness, and extremely juicy for juiciness.

Samples (10 g) of each ground beef batch were collected on days 0 and 7 for analysis, vacuum packaged, and stored frozen (-20ºC) immediately for thiobarbituric acid reactive substances (TBARS) analysis (AOCS, 1998). Secondary lipid oxidation products were measured using the thiobarbituric acid assay (Tarladgis et al. 1960). All samples were transported to Agricultural Utilization Research Institute (AURI, Marshall, MN) for analysis. Samples were evaluated in duplicate and measured with a spectrophotometer (Spectronic 20+, Spectronic Instruments, Inc.) at 532 nm.

Meat blocks were created by combining clods from four animals per dietary treatment. 11.34 kg of ground beef from the combined meat blocks were then combined with a commercial bologna seasoning blend (Bologna SCTP, Newly Wed Food, Chicago, IL), 1.13 kg (2.5 lbs) of ice, sodium tripolyphosphate (30 g per batch), and sodium nitrite cure 30 g per batch (Heller's Modern Cure #47688, Newly Wed Food, Chicago, IL). Ground beef and ingredients were emulsified (Alipina, PB 80-890-II Gossau S G, Switzerland, Speed setting 2, 3-knife head with Alipina tangential form blades) for 10 min to 10º C and then stuffed (Handtmann VF-608, Albert Handtmann Maschimen Fabrik GmbH & Co., Biberach, Germany) into inedible collagen casings (Bologna 10.8 cm Walsrober Casings, Mar/Co Sales, Burnsville, MN). Bologna was cooked to an internal temperature of 65.5º C, (Enviro-Pak, Model CVU 500E-IT, Portland, OR), cooled (12 hours) to 4º C and then sliced. Slices were 12-cm in diameter and 4-mm thick (Globe Slicer, Model 400, Globe Slicing Machine Co, Inc., Stamford, CT).

One slice of bologna from each batch was placed on a polystyrene tray, placed in a vacuum bag (3mil standard barrier, Bunzl PD, North Kansas City, MO) sealed and stored at 4º C under cool white fluorescent lighting (Sylvania H968, 100w, 2, 640 LUX) for ten days. Objective color values (CIE, L*, a*, and b*) were taken at six locations on each slice with Hunter Lab Miniscan EZ (model 4500S, Reston, VA). Subjective color scores (lean color, surface discoloration, and overall appearance) were evaluated by an eight person trained panel for ten days, every other day. Lean color was evaluated on a 1 to 8 scale with 1 = extremely brown and 8 = extremely bright, cured pink. Surface discoloration was evaluated on 1 to 11 scale with 1 = 91-100% discoloration and 11 = 0% discoloration. Overall appearance was evaluated on a 1 to 8 scale with 1 = extremely undesirable and 8 = extremely desirable (AMSA, 1991).

The University of Minnesota Sensory Center conducted sensory evaluation for bologna. Panelists were untrained consumers that were over 18 years old, had no food allergies, and had consumed beef at least twice per month. Panelists were paid for their participation. The University of Minnesota's Institutional Review Board approved all recruiting and experimental procedures. Bologna slices were cut into eight sections and each untrained consumer panelist (n = 87) received two pieces for each replication with three replications per treatment, stored refrigerated, and then served at room temperature. Samples were served to subjects balanced for order and carryover effects. Subjects were asked to taste one piece of the sample and rate it for overall liking, liking of flavor, and liking of texture. Liking ratings were made on 120-point labeled affective magnitude scales, with the left most end labeled strongest dislike imaginable and the right most end labeled strongest like imaginable. Panelists were then instructed to taste the second piece and rate the toughness and off flavor; these ratings were made on 20-point line scales with the left most ends labeled none and the right most ends labeled extremely tough, and extremely intense, respectively

Data were analyzed using the Mixed procedure of SAS 9.3 (SAS Institute, Inc., Cary, NC). Yield grade and QG frequencies were analyzed using the Genmod procedure of SAS. Pen was considered a random effect. The Reg and Robustreg procedures of SAS were used to detect and remove outliers based on DMI and gain. In total, 2 steers were removed from the RFH treatment and 1 steer was removed from the FF treatment. The Contrast statement was used to determine the effect of DG inclusion, inclusion of full-fat versus reduced-fat DG, and concentration of dietary DG inclusion on data. Effects were considered significant when *P* values were less than 0.05 and were considered trends when *P* values were between 0.05 and 0.10.

RESULTS AND DISCUSSION

Dietary treatment effects on cattle growth performance and carcass characteristics are presented in Tables 3 and 4. Contrasts demonstrated no differences in any growth performance or carcass characteristics when comparing full-fat DG inclusion versus reduced-fat DG inclusion in treatment diets.

Dry matter intake tended to be higher ($P = 0.06$) when DG were included in the diet. Dry matter intake for cattle not consuming DG may have been reduced due to poor diet palatability. Furthermore, cattle not consuming DG also consumed higher dietary starch. This may have led to a reduction in rumen pH due to rapid fermentation of starch to VFA. Consequently, cattle not consuming DG may have had rumen upset due to a low rumen pH, possibly experiencing sub-acute rumen acidosis. This also may have contributed to a reduction in DMI.

Contrasts revealed that dietary DG inclusion resulted in greater ($P \leq 0.05$) BW, ADG, and BW gain throughout the entire study Past research has revealed that partially replacing up to 45% grain in feedlot diets with DG may lead to improvements in DMI, ADG, feed efficiency, and BW (Vander Pol et al., 2006; Depenbusch et al., 2009; Anderson et al., 2011; Jaderborg et al., 2012; Luebbe et al., 2012). It is likely that improved dietary energy values contribute to the improved growth performance observed in cattle consuming DG versus other grains.

Contrasts also revealed that HCW, USDA QG, and percentage of cattle grading USDA Choice and Select were improved ($P \leq 0.02$) when DG was included in the diet. The difference in USDA QG between cattle consuming DG and cattle not consuming DG can likely be attributed to differences in ME intake. Cattle consumed 42.8, 57.4, 54.2, and 58.5 Mcal ME daily for the C, RF-O, RF-H, and RF-L treatments respectively. Metabolizable energy intake was lower (P < 0.05) for cattle not consuming DG. This likely contributed to reduced adipose deposition in cattle not consuming DG and consequently an increased number of USDA Select-grading carcasses. It is likely that cattle not consuming DG were not fully finished at harvest, but would produce carcasses with similar USDA QG had they been harvested at a later date.

Including DG at 20 versus 47% of dietary DM tended ($P \leq 0.09$) to result in improved marbling score, 12th rib fat thickness, and USDA QG. Furthermore, 20% dietary DG inclusion led to ($P \leq 0.05$) an increase in percent of cattle grading USDA Prime and a reduction in cattle USDA YG. Improvements in adipose deposition observed in cattle consuming 20 versus 47% DG may be attributed to greater dietary starch intake. This may lead to improved rumen VFA production and consequently improved growth. Several studies have demonstrated that partially replacing dry rolled corn with 15 to 30% full-fat DG led to an increase in rumen VFA production, supporting this hypothesis (Ham et al., 1994; Leupp et al., 2009; Luebbe et al., 2012; Walter et al., 2012). Moreover, Luebbe et al. (2012) revealed that partially replacing dry rolled corn with full-fat DG led to an improvement in 12th rib fat thickness, suggesting that DG have a positive impact on adipose deposition when utilized in low concentrations in dry rolled corn based diets.

Based on the results of this experiment, replacing 20% FFDG with 20% RFDG had no impact on cattle growth performance or carcass characteristics. Moreover, increasing dietary inclusion of RFDG from 20 to 47% may lead to a reduction in USDA Prime grading cattle, but may improve USDA YG. Thus, it can be concluded that RFDG can replace FFDG in feedlot diets at the dietary inclusions investigated in this experiment. Moreover, partially replacing dry rolled corn with DG may lead to an improvement in ADG, HCW, and USDA QG, and a reduction in USDA Select-grading carcasses.

Difference in moisture loss across dietary treatment and breed were not statistically significant. There was a trend in differences in drip loss between breeds; Jersey averaged 1.13% loss while Crossbred measured 0.85% loss ($P = 0.09$). Warner Bratzler Shear Force (WBSF) was not affected by breed ($P=0.09$). CON steaks required more force to shear the cores when compared to all other dietary treatments ($P = 0.09$). The WBSF values range from 2.24 kg for the RF-H group and 2.71 kg for the RF-O. Similar results were seen in studies by Aldai et al. (2010) and Koger et al. (2010) when evaluating corn and wheat WDGS and DDGS at 20-40% in the diet. Shackelford et al, (1991) reported consumer tenderness perception between 3.9 and 4.6 kg of force for slightly tender beef. With that understanding all the values in this study fall into slightly tender or more tender. Rober et al (2005) and Gill et al (2008) found shear force below consumer threshold when cattle were fed distillers grains.

Overall liking did not differ between the two breed treatments ($P = 0.92$). However, panelists preferred the flavor of steaks from the Crossbred cattle ($P = 0.001$) and the texture of steaks from the Jersey cattle ($P =0.03$). Jersey steaks were tougher ($P = 0.001$) yet juicier ($P = 0.001$). Steaks from animals fed the RF-H diet were rated higher as compared to those of the animals fed the RF-L diet for texture liking ($P=0.04$) and flavor liking ($P=0.01$). Panelists preferred the flavor liking of steaks from cattle fed the RF-H and CON diet compared to RF-L. Panelists preferred the texture of the steaks from the steers fed the RF-H to the texture of those from steers fed the RF-L diet. The steaks from the steers fed the CON and RF-O diet were tougher than the steaks from the cattle fed the RF-H diet. Luepp et al. (2009) reported no differences in tenderness, juiciness and flavor in steaks from steers fed 30% DDG in the finishing diet. Haack et al (2011) fed cattle wet distillers grains with solubles at varying concentrations of fat. No differences were found in beef flavor intensity and juiciness. Haack et al (2011) also found control and 4.72% fat WDG beef less tender, with lower levels recorded for off- flavors than 6.91% fat wet distillers grain diet. In the current study there were no differences in off-flavor ($P =0.28$) of steaks across breed and dietary treatments.

Overall liking was greater for bologna from Jersey cattle ($P = 0.001$). Panelists rated higher the flavor ($P = 0.001$) and the texture ($P = 0.03$) of bologna from Crossbred as compared to Jersey cattle. Jersey bologna was tougher (P = 0.01). There was no difference in the overall liking and flavor liking of bologna by dietary treatment.

Dietary treatment had no effect on TBARS for ground beef for day 0 or Day 7 (P = 0.96, 0.96). Ground beef from Crossbred steers had higher TBARS levels on day 0 and day 7 (P = 0.001, 0.001, respectively). Subjective color evaluation, by dietary and breed treatment, was different for lean color (P = 0.01) and a trend was shown for surface discoloration (P = 0.09) for dietary treatment.

L* values for RF-L were higher than CON and RF-O on day two (P = 0.001, 0.03, respectively) and three (P = 0.004, 0.01, respectively). Breed had no effect on L* values (P = 0.24). The a* values for strip steaks were unaffected by diet (P = 0.63) but Jersey steaks were more red (a*) on days two (P = 0.003) and three (P = 0.014). On days three (P = 0.05) and four (P = 0.01), steaks from Jersey cattle (11.6, 12.7) had higher b* values than the steaks from crossbred cattle (10.3, 11.0).

For ground beef patties, starting on day three (P = 0.02) and day four (P = 0.007) lean color was affected by breed. CON recorded the highest values from day 2 until the conclusion of the study, for all three subjective parameters. There was no effect of dietary treatment on subjective surface discoloration (P = 0.21) and overall appearance (P = 0.57), however a trend was found for lean color (P = 0.07). Breed affected surface discoloration (P = 0.0002) and overall appearance (P=0.006). There was a breed effect on objective L* values (P=0.01).

This study suggests that RFDG can replace FFDG in feedlot diets without having a negative impact on growth performance, carcass, or meat quality characteristics up to 20% dietary DM. Moreover, both RFDG and FFDG can effectively replace dry rolled corn in feedlot diets. The increased energy content in feedlot diets containing distillers grains versus dry rolled corn may lead to growth performance and carcass characteristic improvements in cattle harvested at similar time points.

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Table 1. Dietary ingredient inclusion (DM basis)

	Treatment[1]			
	C	RF-O	RF-H	RF-L
Corn oil, %	0.0	0.9	0.0	0.0
Corn silage, %	14.0	13.7	14.4	13.5
Distillers dried grains, %	0.0	19.5	46.7	19.6
Dry rolled corn, %	76.9	60.5	33.2	61.4
Preservative[2], %	0.2	0.1	0.2	0.2
Oat straw, %	3.1	2.9	3.0	3.0
Vitamin and mineral supplement, %	5.9	2.4	2.6	2.4

[1]Treatments included control diet (C), 20% reduced-fat distillers dry grains inclusion with corn oil (FF), 47% reduced-fat distillers dry grains inclusion (RFH), and 20% reduced-fat distillers dry grains inclusion (RFL).
[2]Myco CURB (Kemin, Des Moines, IA) to control mold growth in feed.

Table 2. Dietary nutrient profile (DM basis)

	Treatment[1]			
	C	RF-O	RF-H	RF-L
DM, %[2]	80.6	68.7	69.1	58.2
CP, %	12.1	13.1	20.0	13.2
NDF, %	13.6	16.8	22.0	17.0
ADF, %	7.3	9.3	12.6	9.4
Ether extract, %	3.0	5.0	5.5	4.1
Ca, %	0.67	0.63	0.68	0.63
P, %	0.39	0.50	0.74	0.50
S, %	0.14	0.18	0.28	0.19

[1]Treatments included control diet (C), 20% reduced-fat distillers dry grains inclusion with corn oil (FF), 47% reduced-fat distillers dry grains inclusion (RFH), and 20% reduced-fat distillers dry grains inclusion (RFL).
[2]Water was added to FF, RFH, and RFL treatments to mimic inclusion on distillers wet grains inclusion in diet.

Table 3. Effects of dietary treatment on growth performance

	Treatment[1]					P-value[3]		
	C	RF-O	RF-H	RF-L	SEM[2]	DG vs. no DG inclusion	Full-fat DG vs. reduced-fat DG inclusion	20 vs. 47% DG inclusion
Initial BW, kg	477	490	471	507	31	0.39	0.96	0.09
d 28 BW, kg	486	533	513	534	30	0.005	0.54	0.48
d 56 BW, kg	522	565	545	564	37	0.04	0.58	0.62
d 93 BW, kg	552	593	569	604	41	0.05	0.75	0.24
ADG d 0 to 28, kg	0.32	1.53	1.49	0.94	0.48	< 0.0001	0.21	0.02
ADG d 28 to 56, kg	1.27	1.13	1.12	1.07	0.47	0.45	0.89	0.81
ADG d 56 to 93, kg	0.83	0.84	0.64	1.15	0.40	0.79	0.77	0.04
Gain, kg	75	106	99	99	26	0.03	0.60	0.83
DMI d 0 to 28, kg	6.62	8.80	8.83	9.08	1.04	< 0.0001	0.76	0.61
DMI d 28 to 56, kg	7.96	9.08	9.47	8.81	1.35	0.07	0.93	0.49
DMI d 56 to 93, kg	8.50	8.66	7.60	9.12	1.51	0.96	0.69	0.18
DMI d 0 to 93, kg	7.77	8.82	8.54	9.02	1.16	0.06	0.95	0.55
ADG d 0 to 93, kg	0.81	1.14	1.06	1.07	0.28	0.03	0.60	0.83
Gain: feed d 0 to 93	0.119	0.119	0.139	0.116	0.130	0.75	0.65	0.53

[1]Treatments included control diet (C), 20% reduced-fat distillers dry grains inclusion with corn oil (FF), 47% reduced-fat distillers dry grains inclusion (RFH), and 20% reduced-fat distillers dry grains inclusion (RFL).
[2]Highest standard error of mean reported.
[3]Effects of dietary distillers grains versus no dietary distillers grains inclusion, dietary full-fat versus reduced-fat distillers grains inclusion, and 20 versus 47 percentage dietary distillers grains inclusion. P-values < 0.05 considered significant; P-values ≤ 0.10 considered a trend.

Table 4. Effects of dietary treatment on carcass characteristics

	Treatment[1]					P-value[3]		
	C	RF-O	RF-H	RF-L	SEM[2]	DG vs. no DG inclusion	Full-fat DG vs. reduced-fat DG inclusion	20 vs. 47% DG inclusion
HCW, kg	337	374	360	379	32	0.02	0.78	0.44
Dressing percentage, %	60.8	61.9	63.0	62.5	1.1	0.12	0.50	0.99
Marbling score[4]	424	490	466	537	30	0.19	0.73	0.09
12th rib fat thickness, cm	0.73	0.76	0.82	0.93	0.04	0.43	0.15	0.07
LM area, sq. cm	89.6	95.6	92.5	90.3	0.5	0.47	0.18	0.22
KPH, %	2.3	2.3	2.5	2.5	0.2	0.72	0.22	0.51
USDA YG	2.7	2.8	2.8	2.9	0.1	0.44	0.12	0.05
USDA QG[5]	2.5	2.1	2.2	1.8	0.1	0.004	0.49	0.06
Prime, %	0.4	0.0	0.4	18.2	0.1	0.40	0.18	0.01
Choice, %	50.1	90.0	81.5	80.9	0.1	0.02	0.57	0.75
Select, %	49.6	10.0	18.1	1.0	0.1	0.001	0.91	0.30
USDA YG 2, %	88.2	92.9	87.3	74.1	0.1	0.69	0.22	0.10
USDA YG 3, %	11.8	7.1	12.7	25.9	0.1	0.69	0.22	0.10

[1]Treatments included control diet (C), 20% reduced-fat distillers dry grains inclusion with corn oil (FF), 46% reduced-fat distillers dry grains inclusion (RFH), and 20% reduced-fat distillers dry grains inclusion (RFL).
[2]Highest standard error of mean reported.
[3]Effects of dietary distillers grains versus no dietary distillers grains inclusion, dietary full-fat versus reduced-fat distillers grains inclusion, and 20 versus 47 percentage dietary distillers grains inclusion. P-values < 0.05 considered significant; P-values ≤ 0.10 considered a trend.
[4]Marbling score 400 = low choice and 500 = average choice.
[5]USDA QG 1 = Prime, 2 = Choice, and 3 = Select.

Table 5. Least squared means for vacuum purge, Ultimate pH, drip loss, and Warner-Bratzler shear force by dietary treatment

	Treatment					
	C	RF-O	RF-L	RF-H	SE	P value
Purge, %	0.01	0.01	0.69	0.01	0.26	0.20
pH	5.51	5.49	5.07	5.48	0.16	0.20
Drip, %	0.874	0.168	1.062	1.334	0.173	0.066
Shear Force	3.01	2.71	2.69	2.24	0.20	0.09

Table 6. Least squared means for vacuum purge, Ultimate pH, drip loss, and Warner-Bratzler shear force by breed treatment

	Treatment			
	Jersey	Crossbred	SE	P value
Purge, %	0.35	0.02	0.18	0.21
pH	5.28	5.48	0.11	0.22
Drip, %	1.13	0.85	0.12	0.09
Shear Force	2.79	2.96	0.14	0.21

Table 7. Least squared means for sensory characteristics of fresh strip steaks by dietary treatment

	Treatment					
	C	RF-O	RF-L	RF-H	F	P values
Overall Liking	68.0[ab]	67.0[ab]	65.0[b]	70.0[a]	2.90	0.03
Flavor Liking	70.0[a]	68.0[ab]	65.0[b]	72.0[a]	5.30	0.00
Texture Liking	67.0[ab]	66.0[ab]	64.0[b]	70.0[a]	2.50	0.06
Off flavor	7.9[a]	7.5[a]	7.2[a]	6.5[a]	1.30	0.28
Toughness	5.5[a]	5.5[a]	5.5[ab]	5.2[b]	4.10	0.01
Juiciness	4.6[a]	4.4[a]	5.1[a]	4.8[a]	0.40	0.75

Table 8. Least squared means for sensory characteristics of fresh strip steaks by breed treatment

	Treatment			
	Jersey	Crossbred	SE	P value
Overall Liking	67.00	68.00	0.01	0.92
Flavor Liking	70.00	67.00	4.50	0.03
Texture Liking	64.00	70.00	13.00	<0.001
Off flavor	7.80	6.70	2.90	0.09
Toughness	4.50	6.30	12.20	<0.001
Juiciness	4.50	5.00	40.90	<0.001

Table 9. Least squared means for thiobarbituric acid reactive substances by dietary treatment

	Treatment					
	C	RF-O	RF-L	RF-H	SE	P values
TBARS Day 0	0.83	0.60	0.66	0.72	0.19	0.96
TBARS Day 7	2.81	2.96	2.83	2.97	0.19	0.96

Table 10. Least squared means for thiobarbituric acid reactive substances by breed treatment

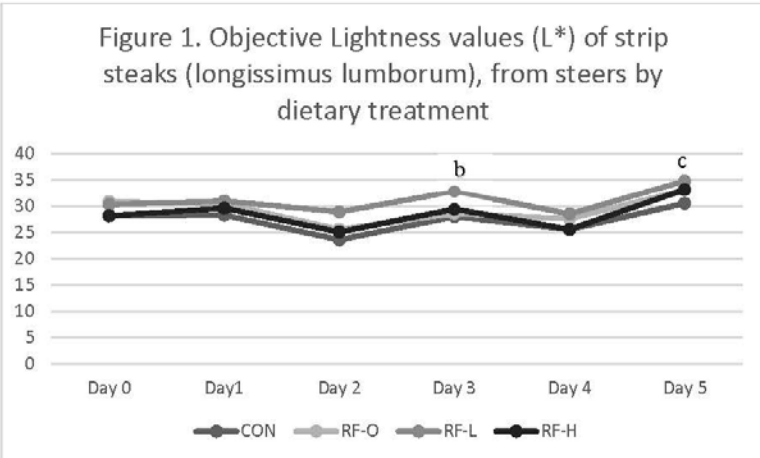
	Treatment			
	Jersey	Crossbred	SE	P value
TBARS Day 0	0.48	0.87	0.14	<0.001
TBARS Day 7	2.56	3.27	0.14	<0.001

Table 11. Least squared means for sensory characteristics of Bologna by dietary treatment

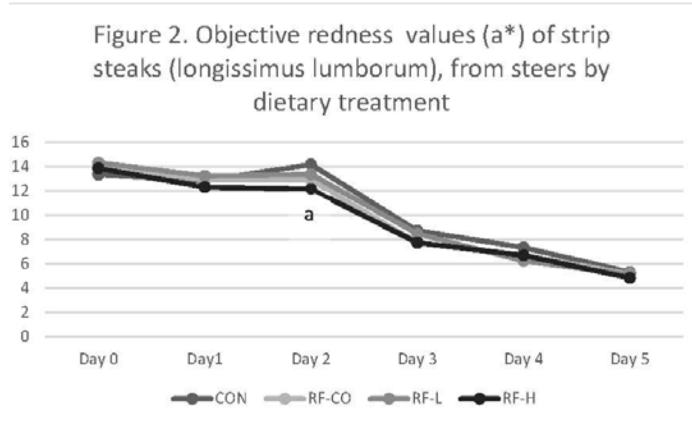
	Treatment					
	C	RF-CO	RF-L	RF-H	F	P values
Overall Liking	71.0	70.0	69.0	68.0	2.30	0.07
Flavor Liking	71.0	70.0	69.0	68.0	2.20	0.09
Texture Liking	72.0^{a}	70.0^{a}	70.0^{ab}	67.0^{b}	4.10	0.01
Off flavor	3.7	3.8	4.0	4.0	0.90	0.45
Toughness	4.7^{b}	3.8^{c}	4.7^{b}	6.6^{a}	36.60	<0.001

Table 12. Least squared means for sensory characteristics of Bologna by breed treatment

	Treatment			
	Jersey	Crossbred	SE	P value
Overall Liking	71.0^{a}	68.0^{b}	15.00	<0.001
Flavor Liking	71.0^{a}	68.0^{b}	11.90	<0.001
Texture Liking	71.0^{a}	68.0^{b}	5.80	0.02
Off flavor	4.0	3.8	1.60	0.09
Toughness	5.0	4.4	28.90	<0.001



[a] CON is different than RF-O, RF-O different then RF-L, RF-L different than RF-H
[b] CON diferent from RF-O, RF-O different from RF-L
[c] CON different from RF-L



CON different from RF-H

Figure 3. Objective yellowness values (b*) of strip steaks (longissimus lumborum), from steers by dietary treatment

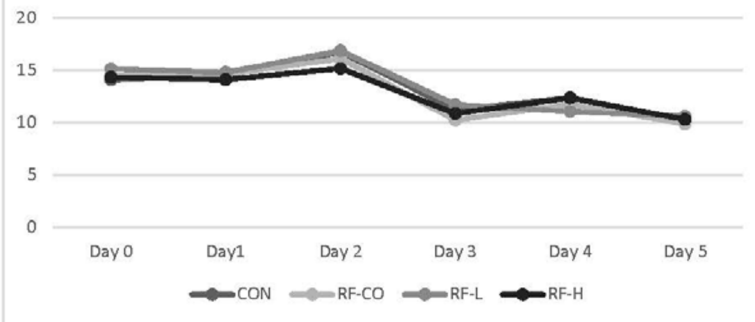
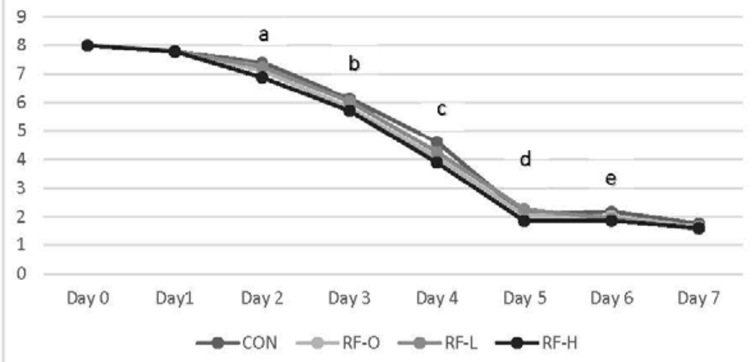
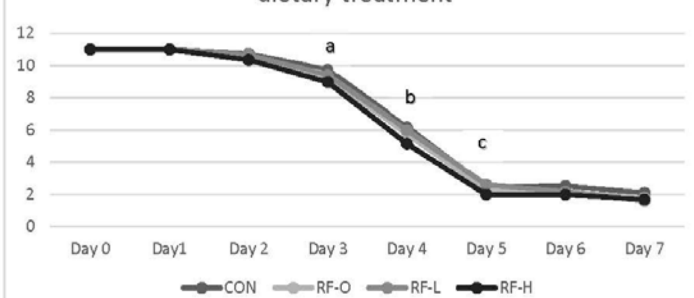


Figure 4. Subjective lean color appearance of strip steaks (longissimus lumborum), from steers by dietary treatment

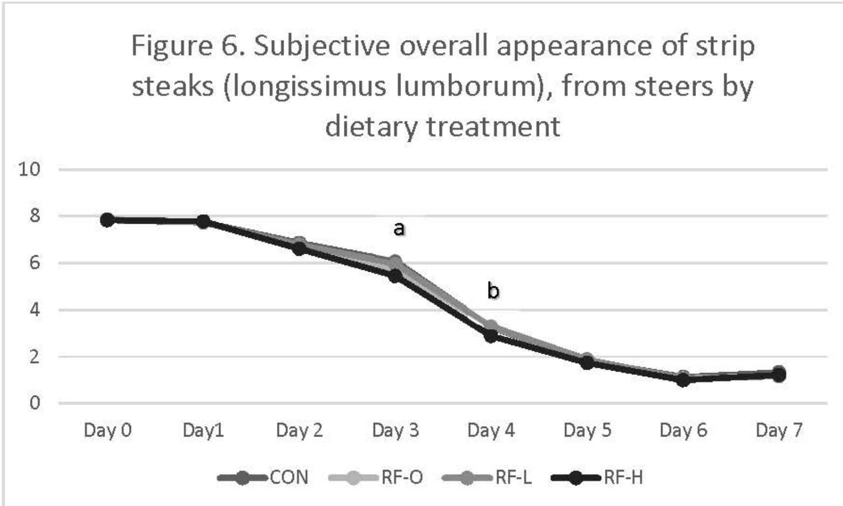


[a]CON different from RF-H, RF-L different from RF-H
[b]CON different from RF-H, RF-L different from RF-H
[c]CON different from RF-O, RF-L different from RF-H
[d]RF-L different from RF-H
[e]CON different from RF-H

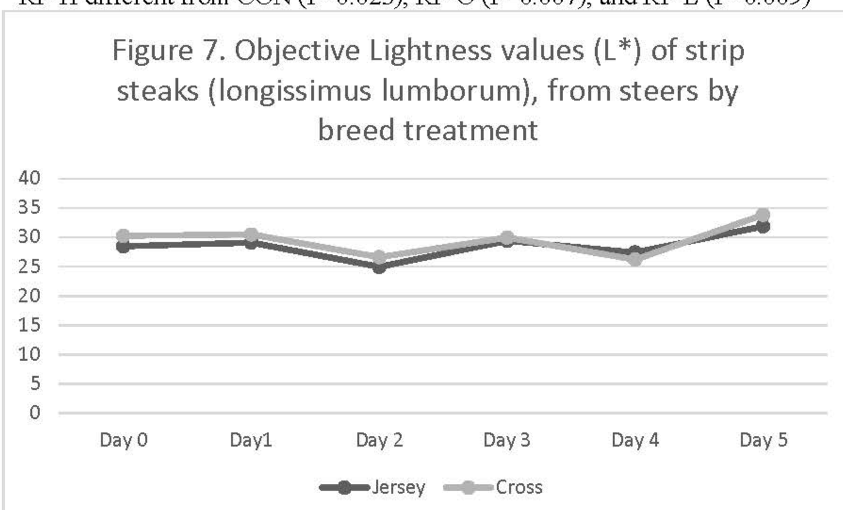
Figure 5. Subjective surface discoloration of strip steaks (longissimus lumborum), from steers by dietary treatment



[a]CON different from RF-H (P=0.013)
[b] RF-H different from CON (P=0.001), RF-O (P=0.037), and RF-L (P=0.004)
[c]RF-L different from RF-H (P=0.031)



[a]CON different from RF-O (P=0.39) and RF-H (P=0.001), RF-L different from RF-H (P=0.001)
[b] RF-H different from CON (P=0.023), RF-O (P=0.007), and RF-L (P=0.009)



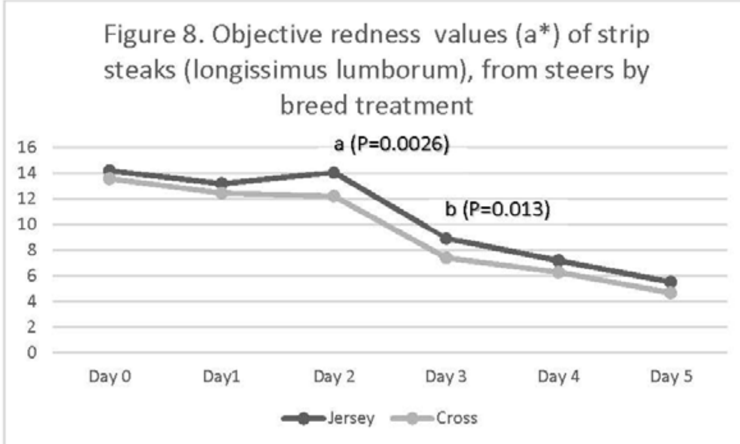


Figure 8. Objective redness values (a*) of strip steaks (longissimus lumborum), from steers by breed treatment
a (P=0.0026)
b (P=0.013)
16
14
12
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Jersey
Cross

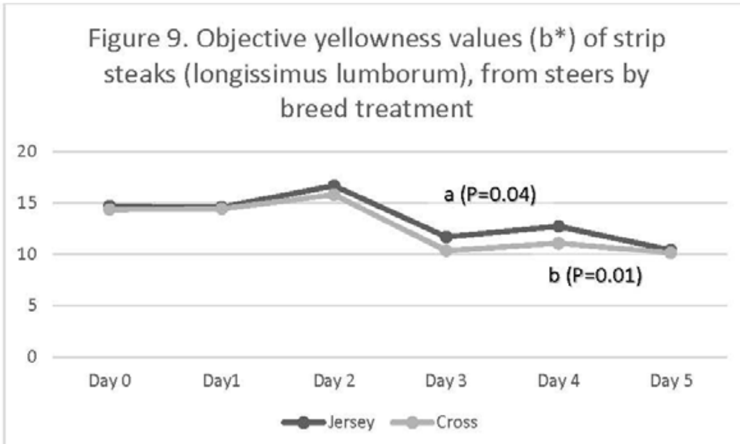


Figure 9. Objective yellowness values (b*) of strip steaks (longissimus lumborum), from steers by breed treatment
20
15
10
5
0
a (P=0.04)
b (P=0.01)
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Jersey
Cross

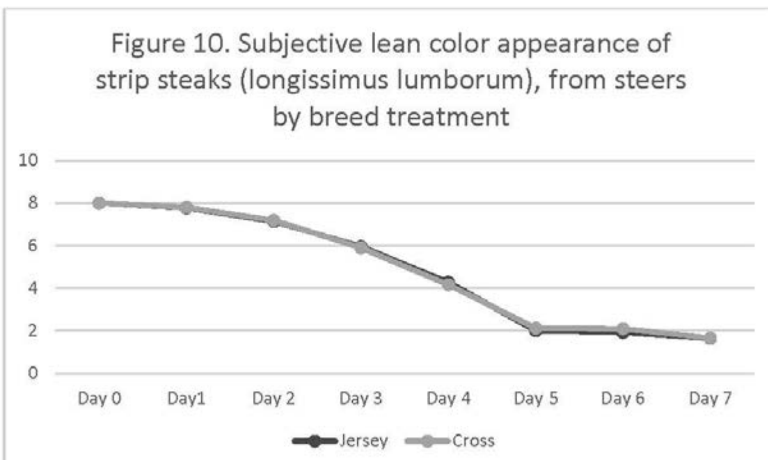


Figure 10. Subjective lean color appearance of strip steaks (longissimus lumborum), from steers by breed treatment
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

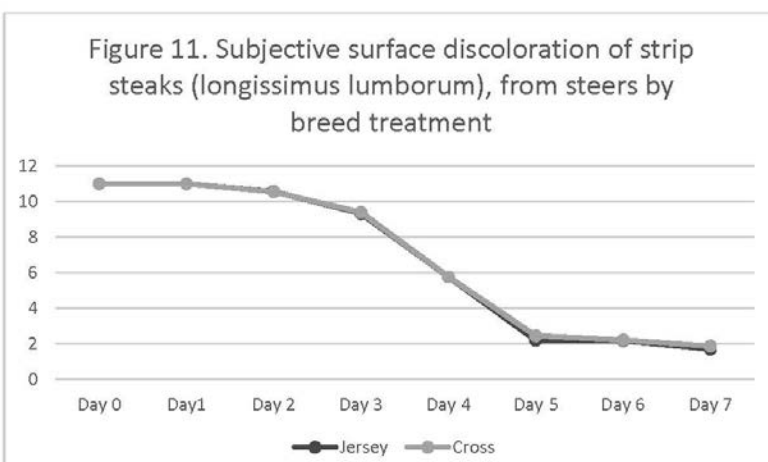


Figure 11. Subjective surface discoloration of strip steaks (longissimus lumborum), from steers by breed treatment
12
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

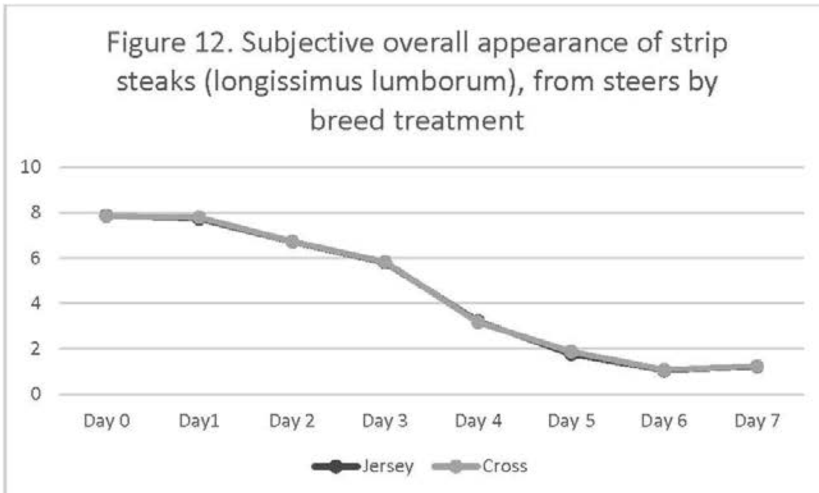


Figure 12. Subjective overall appearance of strip steaks (longissimus lumborum), from steers by breed treatment
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

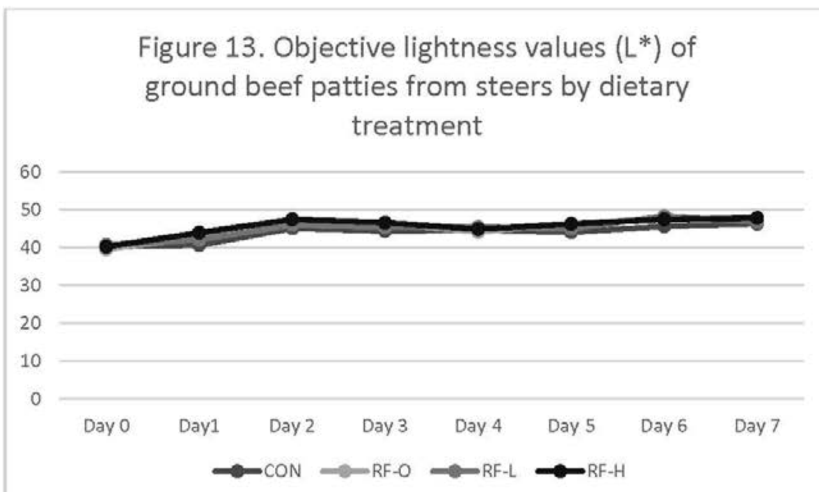


Figure 13. Objective lightness values (L*) of ground beef patties from steers by dietary treatment
60
50
40
30
20
10
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
CON
RF-O
RF-L
RF-H

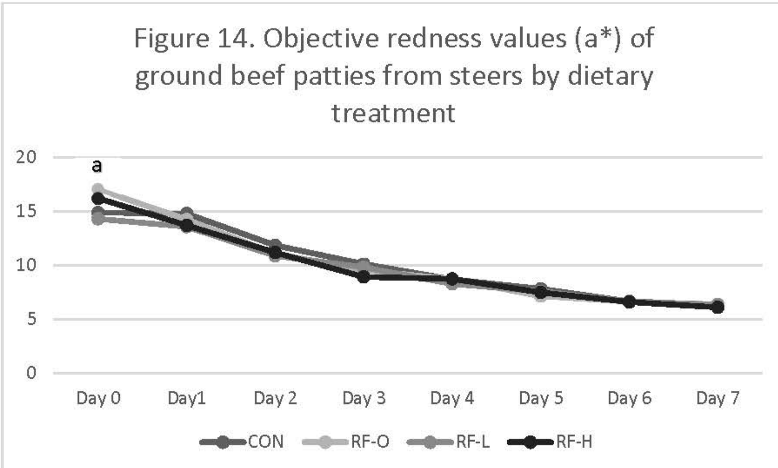


Figure 14. Objective redness values (a*) of ground beef patties from steers by dietary treatment

[a]CON different from RF-O (P=0.002) and RF-H (P=0.024), RF-O different from RF-L (P=0.001), RF-L different from RF-H (P=0.002)

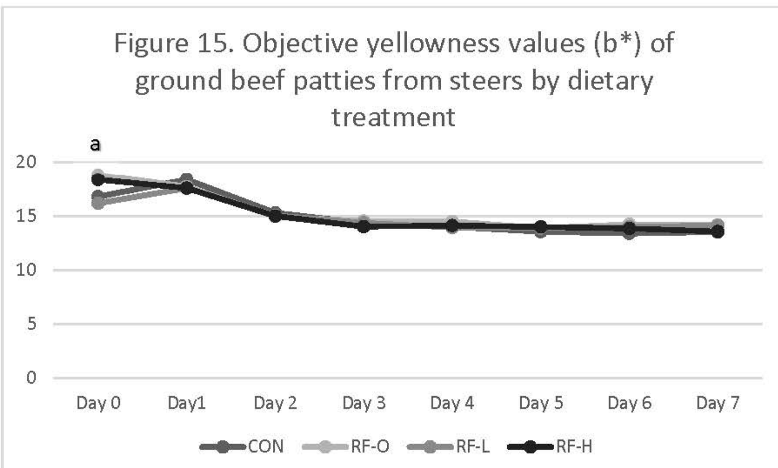


Figure 15. Objective yellowness values (b*) of ground beef patties from steers by dietary treatment

[a]CON different from RF-O (P=0.002) and RF-H (P=0.012), RF-O different from RF-L (P=0.001), RF-L different from RF-H (P=0.001)

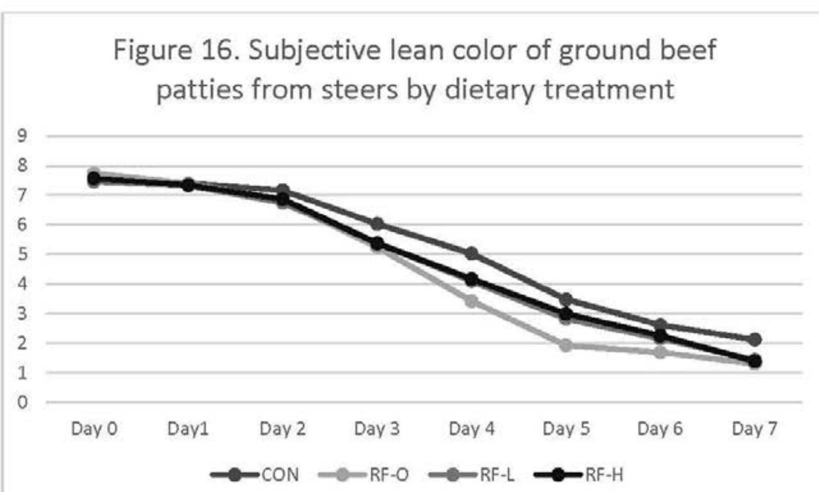


Figure 16. Subjective lean color of ground beef patties from steers by dietary treatment

Figure 17. Subjective surface discoloration of ground beef patties from steers by dietary treatment

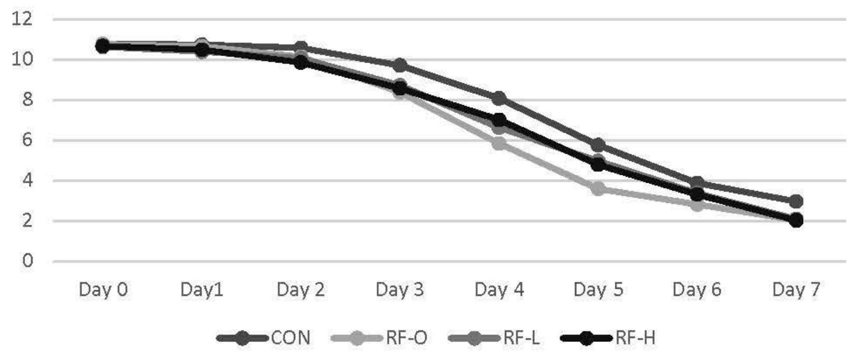
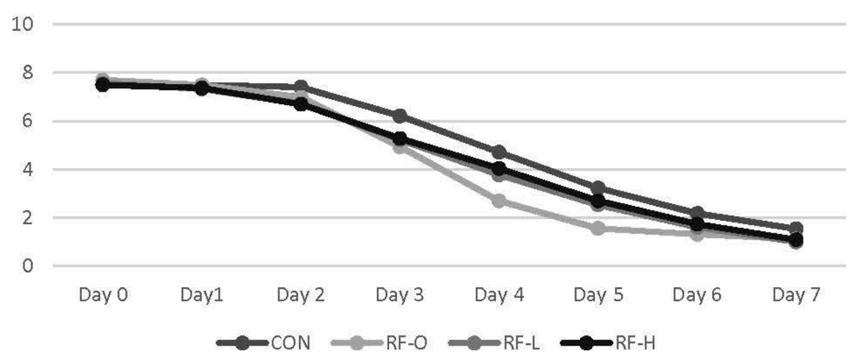


Figure 18. Subjective overall appearance of ground beef patties from steers by dietary treatment



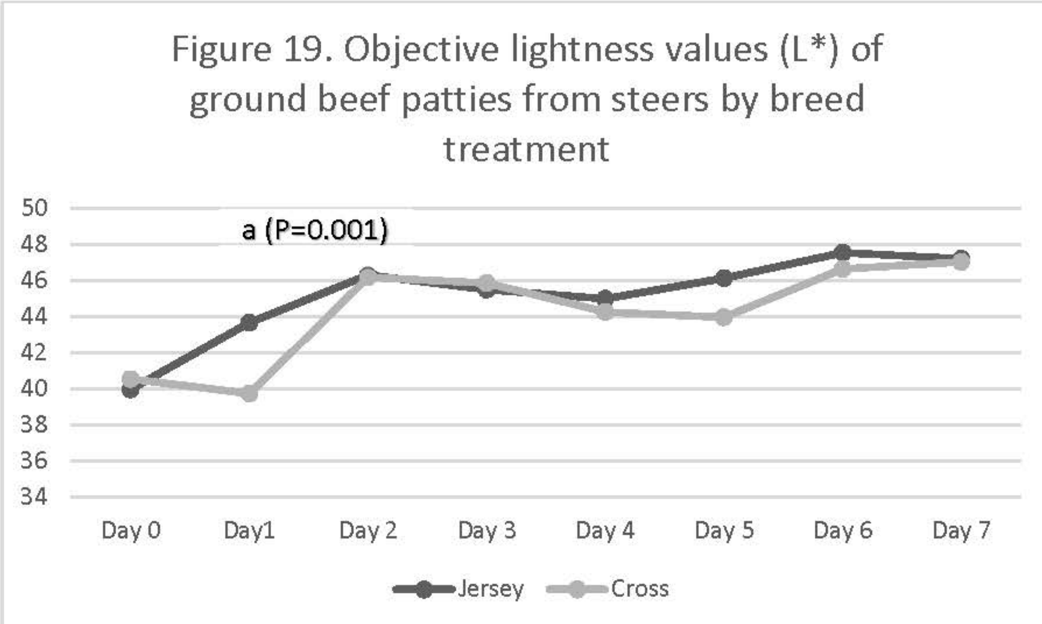


Figure 19. Objective lightness values (L*) of ground beef patties from steers by breed treatment
a (P=0.001)
50
48
46
44
42
40
38
36
34
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

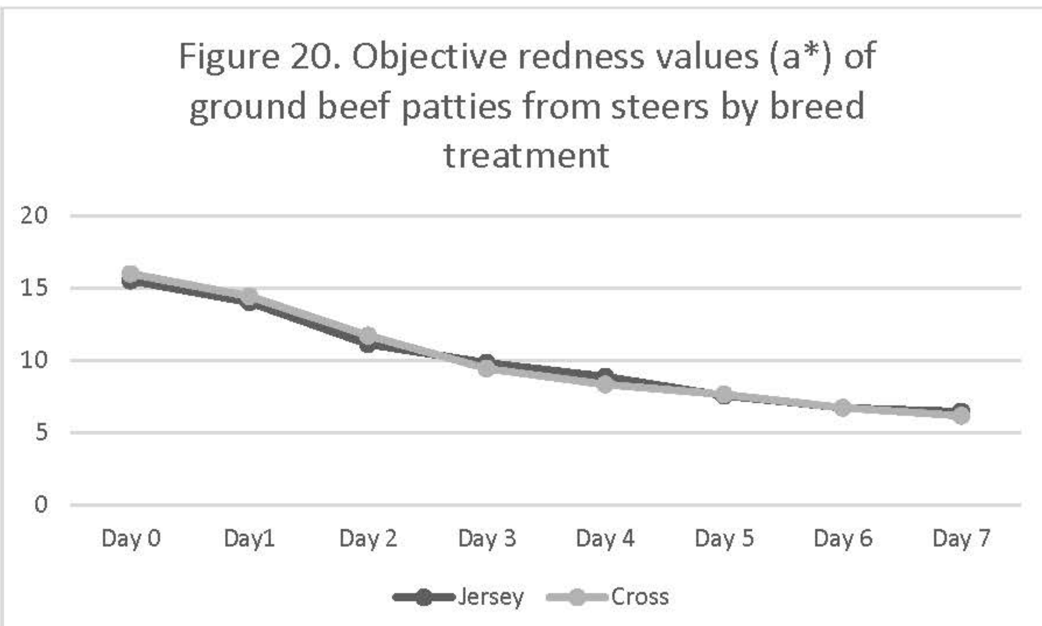


Figure 20. Objective redness values (a*) of ground beef patties from steers by breed treatment
20
15
10
5
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

Figure 21. Objective yellowness values (b*) of ground beef patties from steers by breed treatment

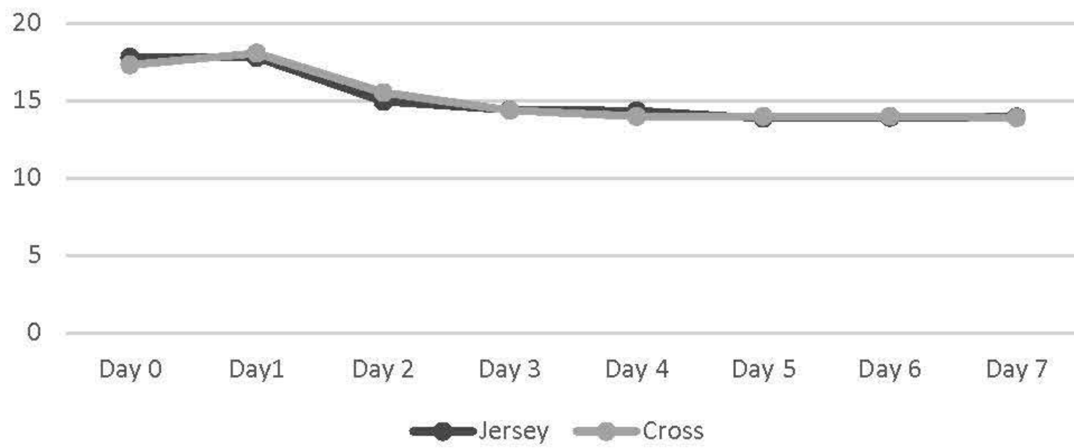
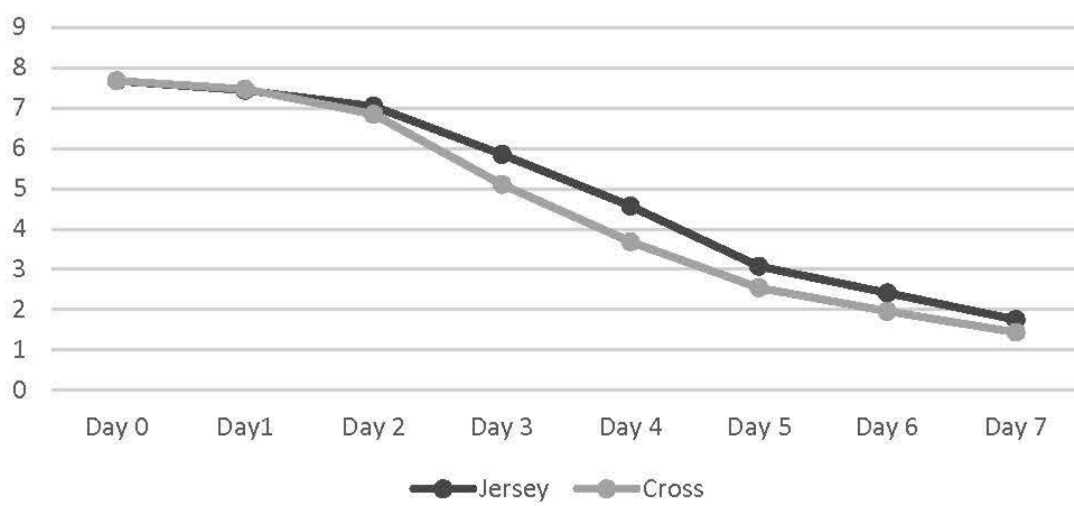


Figure 22. Subjective lean color of ground beef patties from steers by breed treatment



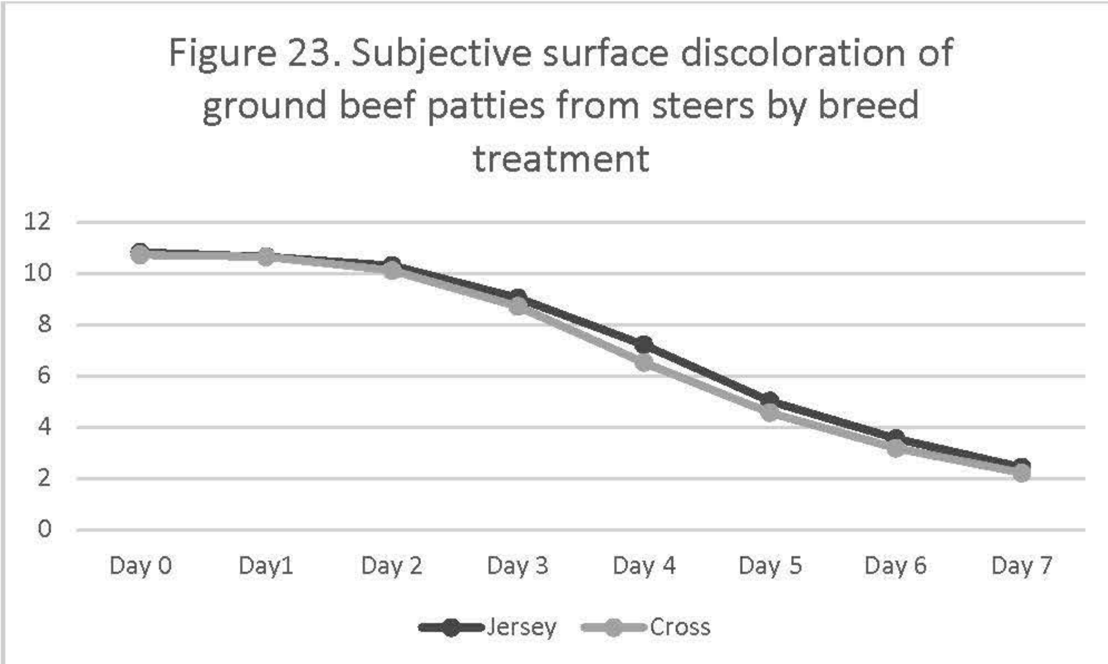


Figure 23. Subjective surface discoloration of ground beef patties from steers by breed treatment
12
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

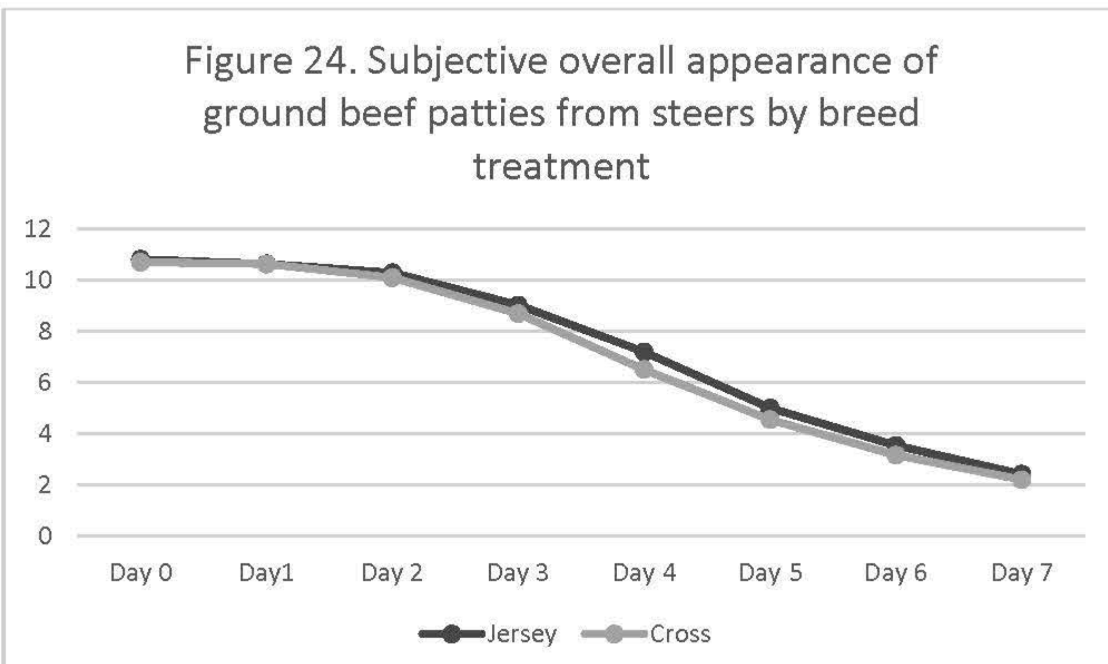


Figure 24. Subjective overall appearance of ground beef patties from steers by breed treatment
12
10
8
6
4
2
0
Day 0
Day1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Jersey
Cross

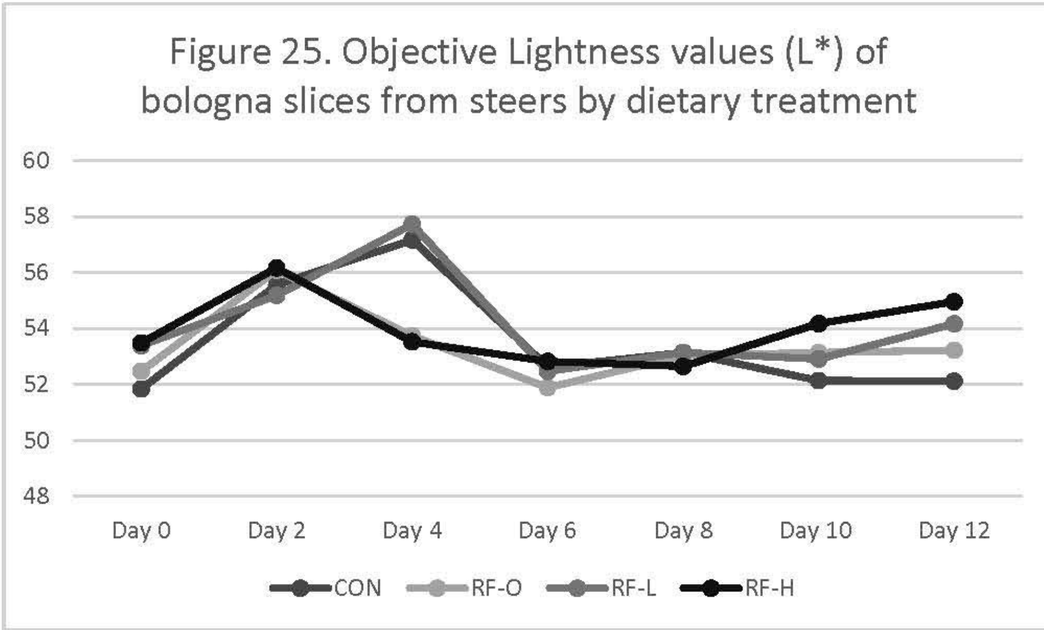


Figure 25. Objective Lightness values (L*) of
bologna slices from steers by dietary treatment
60
58
56
54
52
50
48
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Day 12
CON
RF-O
RF-L
RF-H

Figure 26. Objective redness values (a*) of bologna slices from steers by dietary treatment

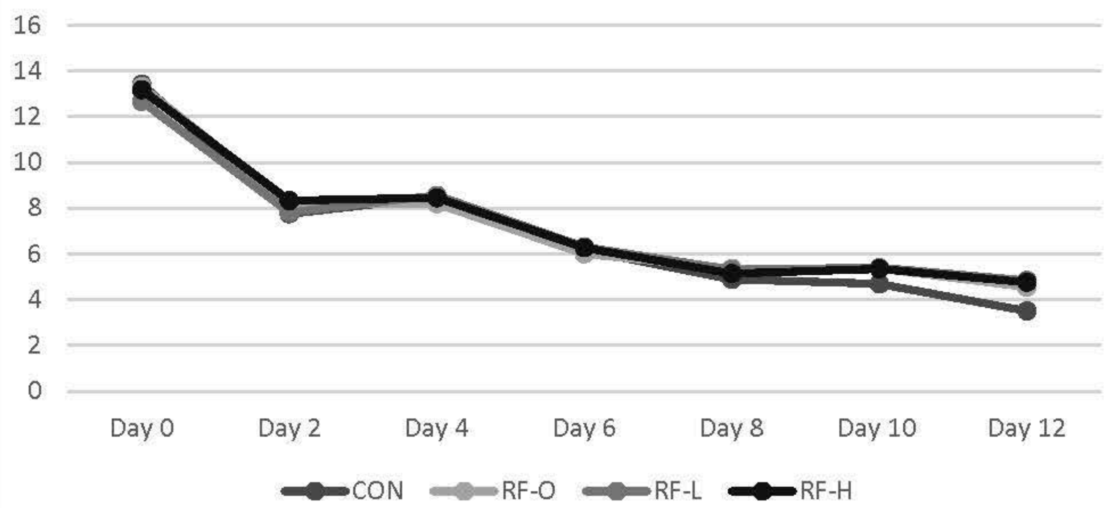


Figure 27. Objective yellowness values (b*) of bologna slices from steers by dietary treatment

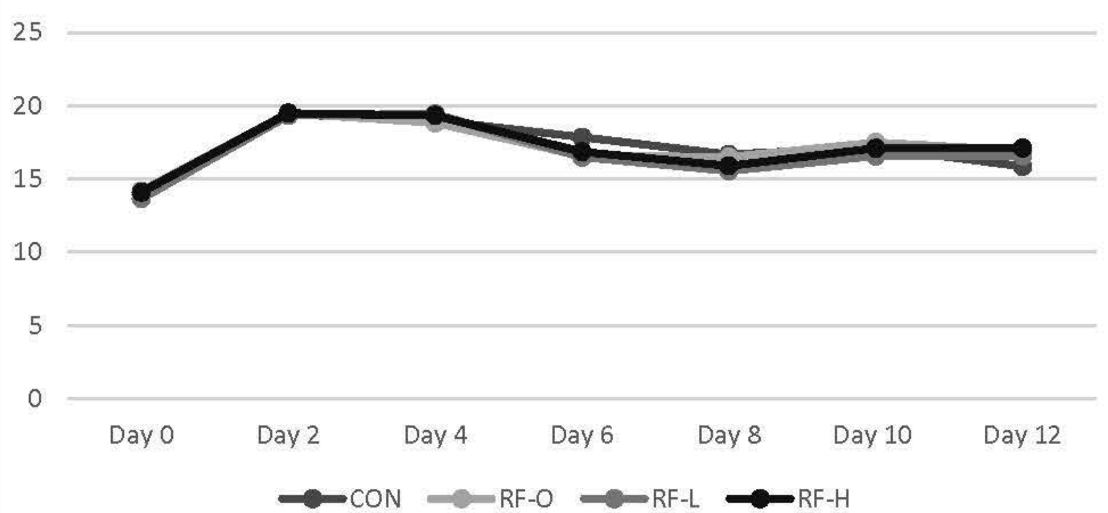


Figure 28. Subjective lean color of bologna slices from steers by dietary treatment

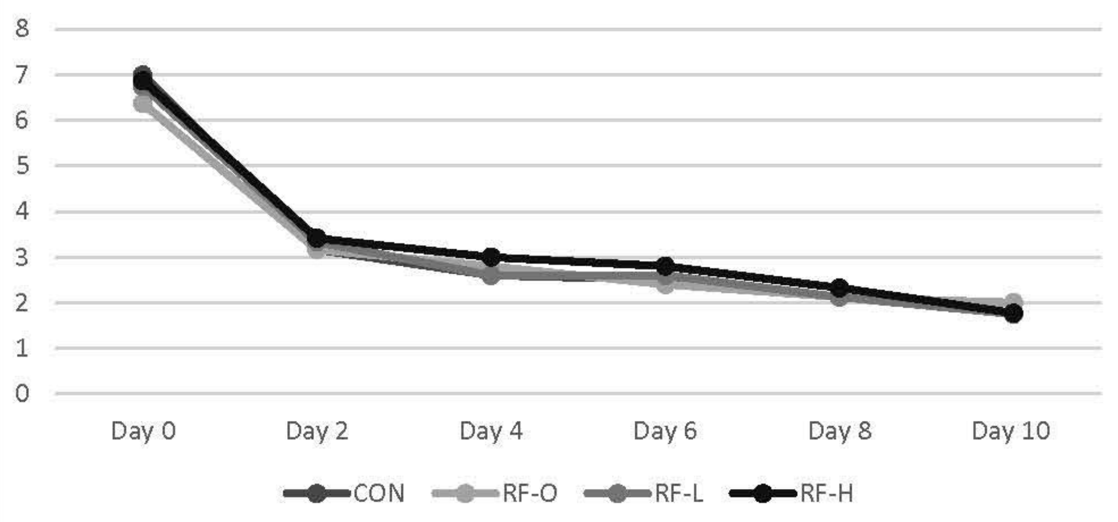


Figure 29. Subjective surface discoloration of bologna slices from steers by dietary treatment

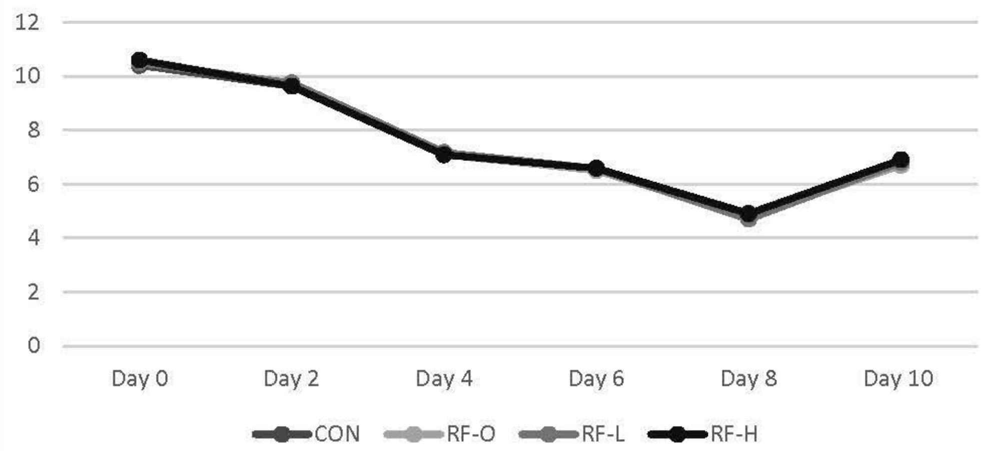
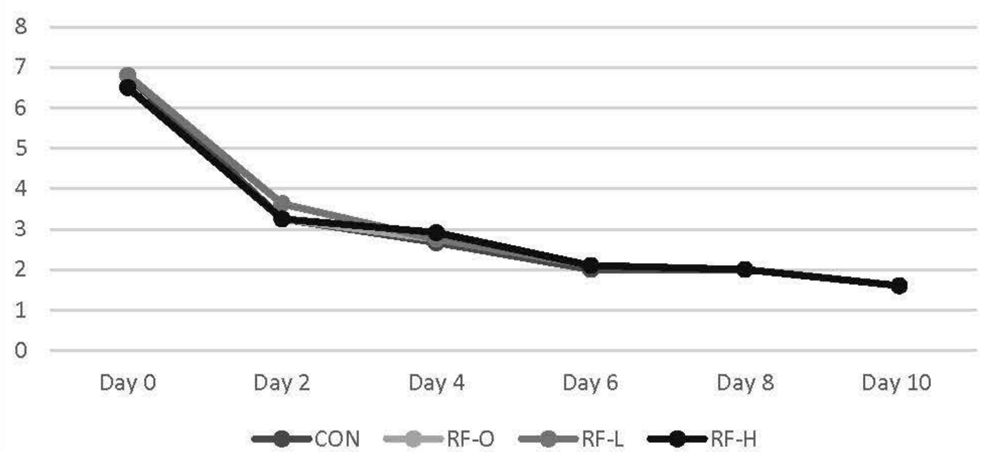


Figure 30. Subjective overall appearance of bologna slices from steers by dietary treatment



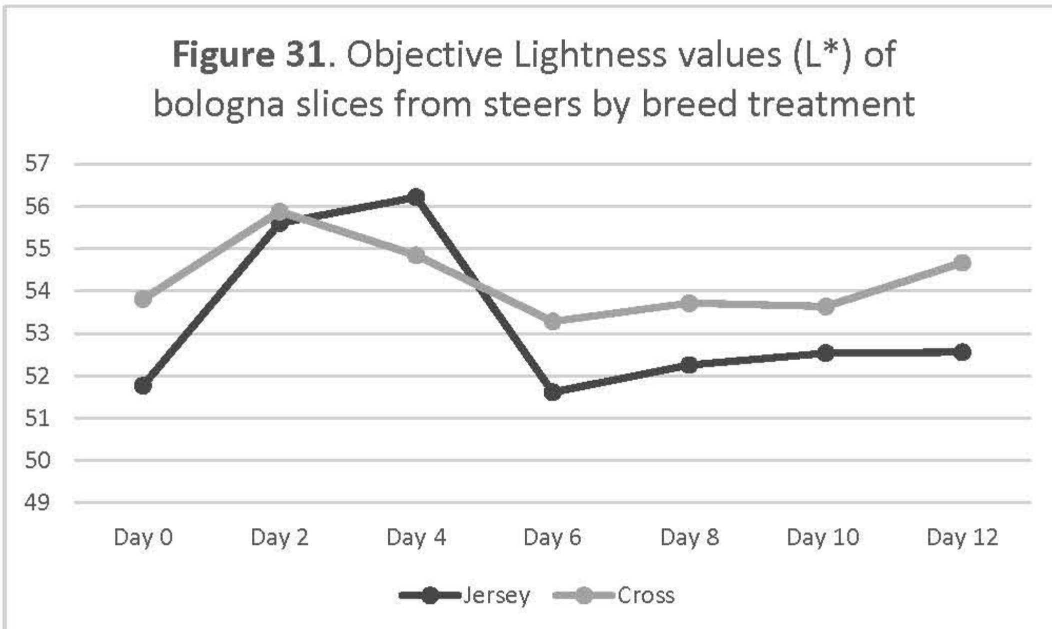


Figure 31. Objective Lightness values (L*) of bologna slices from steers by breed treatment
57
56
55
54
53
52
51
50
49
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Day 12
Jersey
Cross

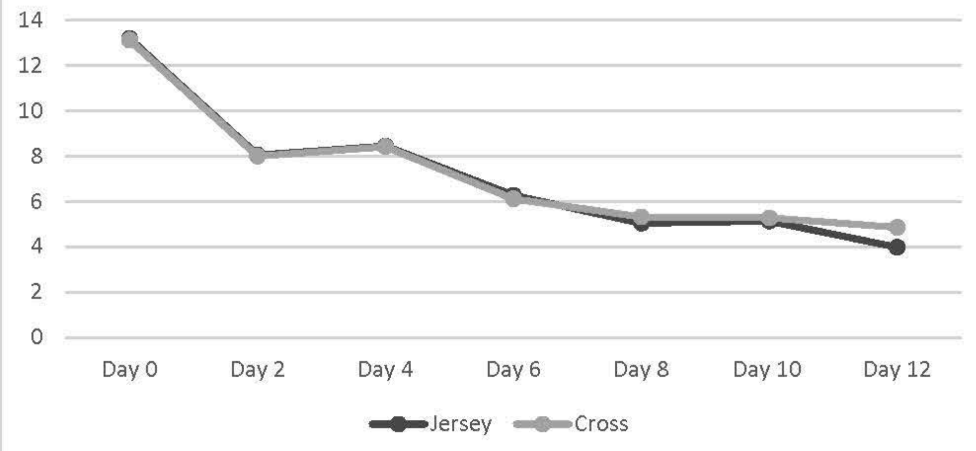


Figure 32. Objective redness values (a*) of bologna slices from steers by breed treatment

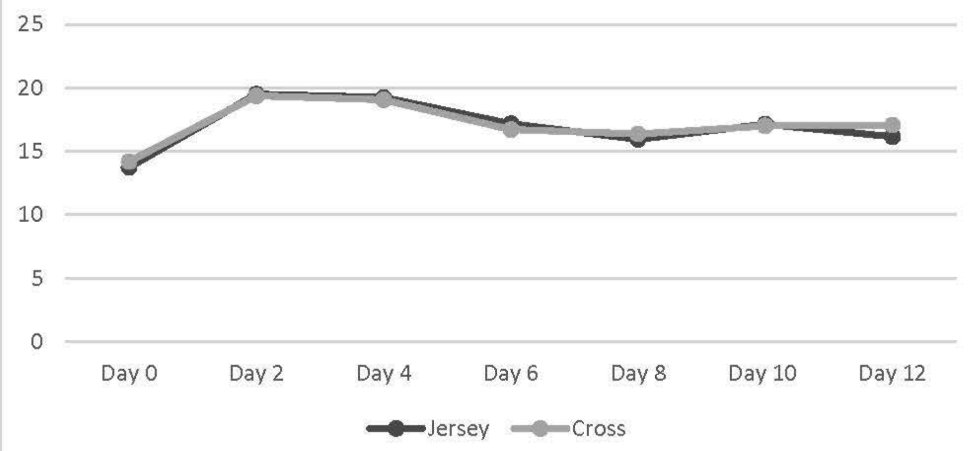


Figure 33. Objective yellowness values (b*) of bologna slices from steers by breed treatment

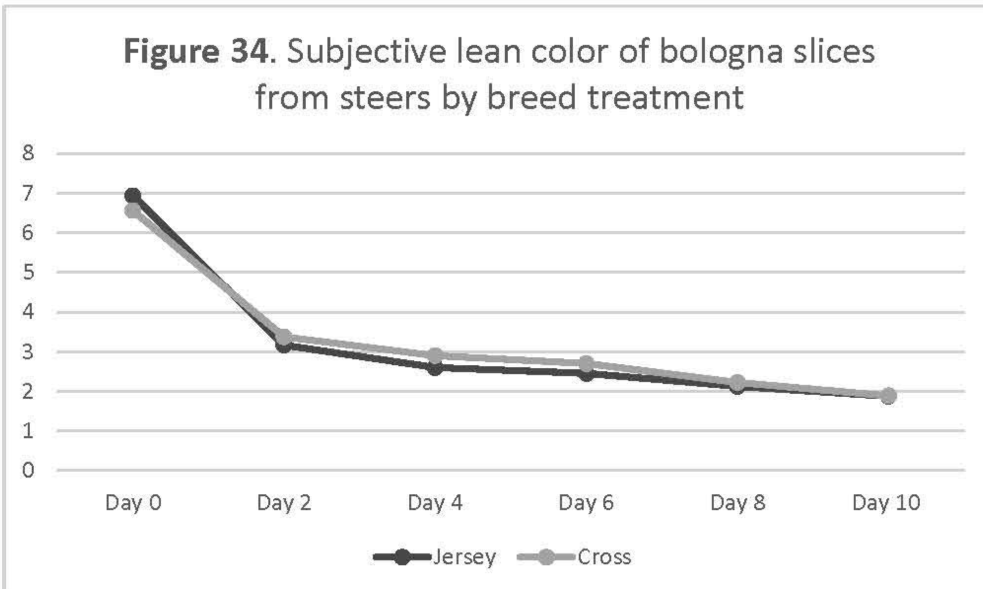


Figure 34. Subjective lean color of bologna slices from steers by breed treatment
8
7
6
5
4
3
2
1
0
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Jersey
Cross

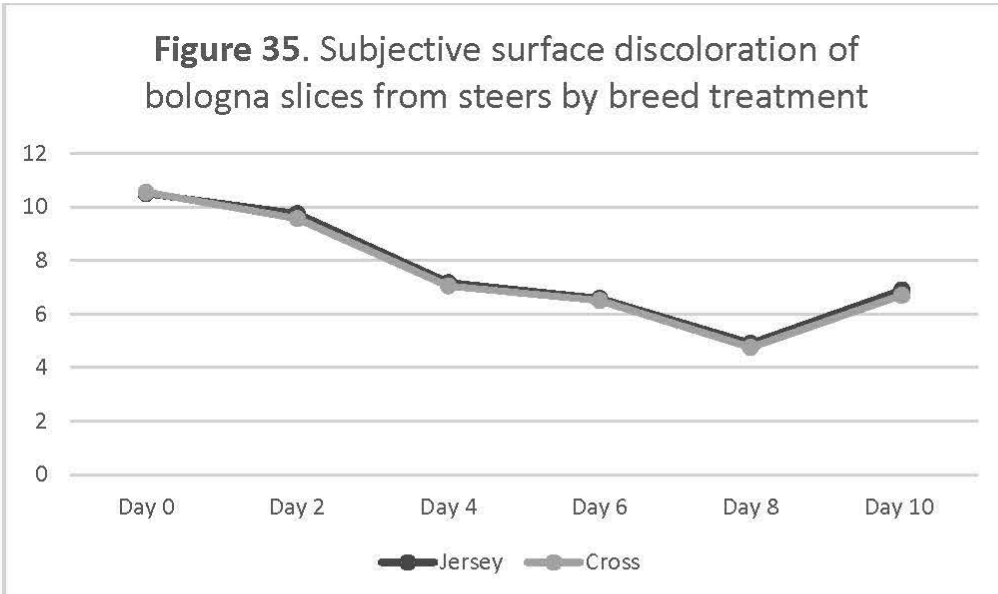


Figure 35. Subjective surface discoloration of bologna slices from steers by breed treatment
12
10
8
6
4
2
0
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Jersey
Cross

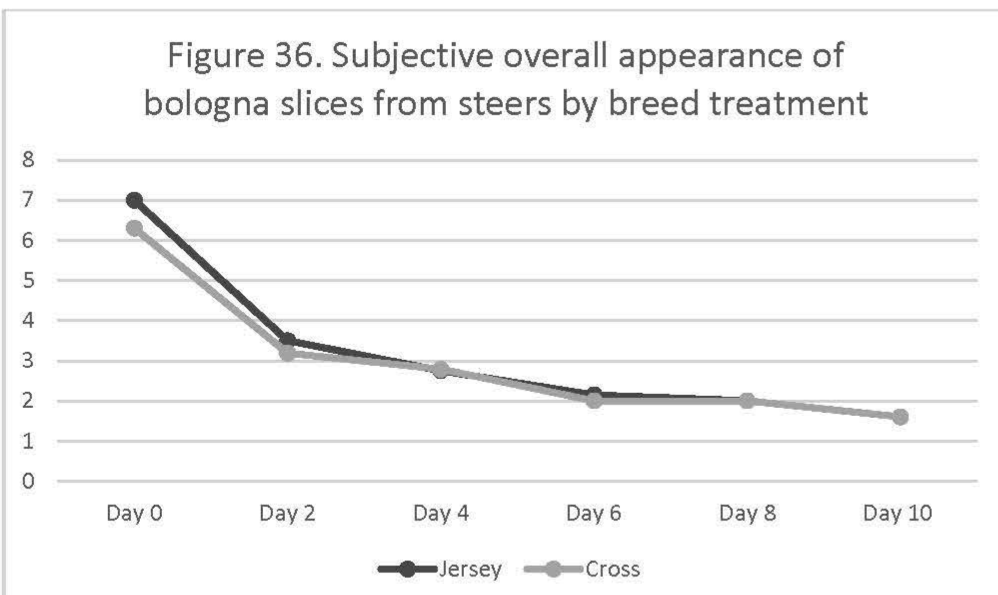


Figure 36. Subjective overall appearance of bologna slices from steers by breed treatment
8
7
6
5
4
3
2
1
0
Day 0
Day 2
Day 4
Day 6
Day 8
Day 10
Jersey
Cross