New or modified feed ingredients are becoming available from new or modified ethanol production processes. Specifically, some ethanol plants have begun to produce high protein dried distillers grains by separating the corn oil from the stillage. The resulting co-product contains more protein and less fat than traditional distillers grains plus solubles. There is little research to show how these new co-products impact livestock performance and meat quality. This research provides feedlot managers and livestock producers with more information about these new feed products. Ethanol facilities may also benefit from this research by having access to more data on feed performance for high protein dried distillers grains.

This research addresses the issue of high dietary fat levels that have been found with livestock rations containing wet or dried distillers grains with solubles. These increased levels of polyunsaturated fats can limit the acceptable inclusion for distillers grains in certain livestock diets. The benefits of high protein dried distillers grains may be increased utilization and lower feed costs. This research explores the utilization of low oil distillers grains in beef cattle. Higher inclusion rates in dairy rations may also be warranted, but were not the focus of this research. The inclusion of high protein dried distillers grains at the highest rate had a detrimental effect on meat quality, although the decrease in meat quality was small. Further studies are needed to understand the cause of the decrease in meat quality and the specific feeding practices which may eliminate any impact on meat quality from the inclusion of high protein dried distillers grains in beef rations.

A special thank you is given to Dr. Ryan Cox. This study represents the culmination of a successful partnership between the AURI Meat Products and Analytical Chemistry Laboratories in Marshall and the Animal Science and Extension programs at the University of Minnesota. The support of the Minnesota Corn Growers Research & Promotion Council is gratefully acknowledged.

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FINAL REPORT

Project Title: Effect of finishing cattle on high protein dried distillers grains on animal performance and carcass and meat characteristics.

Submitted To:

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SUMMARY

The research objective of this experiment was to replace 35% of dry rolled corn in traditional corn-based feedlot diets with a high protein dried distillers grains and view its effects on steer performance, carcass characteristics, and subsequent meat quality characteristics, shelf-life stability, and consumer acceptance. Angus steers (n = 48) were individually fed one of three dietary treatments in the finishing phase that included a conventional corn based finishing diet (**CON**); a treatment containing 35% dried distillers grains with solubles replacing CON (**DDGS**); and a treatment containing 35% high protein dried distillers grains replacing CON (**HPDDG**). There were no differences ($P > 0.05$) among treatments for all carcass characteristics. Moisture losses and shear force values did not differ among treatments ($P > 0.05$). Consumer sensory scores did not differ among treatments ($P > 0.05$) for strip steaks. Cooked sausage from CON rated the highest for overall liking and flavor liking ($P = 0.01$ and $P = 0.04$, respectively). Sausages from CON and HPDDG were rated higher for texture liking ($P = 0.01$) than those from DDGS. For strip steak objective shelf life, a* values were lower for DDGS and HPDDG ($P < 0.001$) as compared to CON. Treatment affected subjective scores for lean color, surface discoloration and overall appearance ($P < 0.001$) of strip steaks. For ground beef, summer sausage, and bologna objective shelf life, L*, a*, or b* ($P = 0.15$, 0.16, and 0.23 respectively) mean values were not affected by treatment. Ground beef had a more desirable subjective lean color ($P = 0.001$) and overall appearance ($P = 0.001$) for CON than DDGS and HPDDG. Treatment had no effect on saturated fatty acid and monounsaturated fatty acid percentage ($P = 0.44$ and 0.86 respectively), however; treatment did affect polyunsaturated fatty acid ($P = 0.0001$), with CON having lower values than DDGS and HPDDG. TBARS indicated no difference between treatments on d 0 ($P = 0.50$) for lipid oxidation in ground beef, however, on d 7 HPDDG had increased values as compared to DDGS and CON ($P = 0.001$). Results indicate that beef

cattle finishing diets containing up to 35% HPDDG in place of corn can be fed without affecting characteristics of fresh beef products. This inclusion level, however, may produce unfavorable changes in sensory characteristics of cooked sausage. Including 35% HPDDG in beef cattle finishing diets also increases lipid oxidation resulting in a decrease in shelf life in fresh and further processed beef products.

INTRODUCTION

In the United States, beef cattle consumed an estimated 41% of the total distillers grains (DGS) produced in 2010 (RFA, 2011). Producers are likely to feed DGS due to their high energy value, flexibility in feeding, price and availability (Hussein et al., 1995; Stock et al., 2000; Klopfenstein et al., 2008). As ethanol plants look to increase revenue and efficiency, fractionated corn co-products have become available to feedlot producers; however, there are limited published data on effects of feeding fractionated corn co-products in beef finishing diets on carcass quality, particularly on beef quality and sensory attributes.

Depenbusch et al. (2008) fed heifers diets containing either a partially fractionated dried distillers grains (DDG), a traditional DDG, or a corn-based control diet with no DDG and found no differences for hot carcass weight (HCW), dressing percentage, ribeye area (REA), 12th rib back fat, marbling score or USDA Yield Grade and Quality Grade. Gigax et al. (2011) fed conventional wet DGS (WDGS) containing 12.9% fat and a fractionated WDGS containing 6.7% fat and reported final body weight (BW) and HCW were greater for steers fed conventional WDGS than the steers fed the fractionated WDGS and the control diet. There were no differences in ribeye area (REA), 12th rib back fat, and marbling between steers fed conventional WDGS and fractionated WDGS.

Quality of beef is ultimately determined by the consumer, who investigates each meat product to ensure it is fresh. Although color is the primary determinant in the consumer's decision to purchase beef, flavor, tenderness and juiciness are the primary indicators of palatability (Voges et al., 2007). Jenschke et al. (2007) found that feeding dried DGS does not impact tenderness or sensory attributes of beef. Similarly, Leupp et al. (2009) reported that juiciness was rated highest in steaks from steers fed 30% dried DGS during the growing and finishing phases, while juiciness and off-flavor were not different among cattle fed corn dried DGS (Depenbusch et al., 2009) or sorghum DGS (Gill et al., 2008), and a corn-based control. Warner-Bratzler shear force (WBSF) values of steaks from cattle fed 25-50% WDGS or dried DGS, wheat DGS (Aldai et al., 2010) sorghum DGS or corn-based controls did not differ (Koger et al., 2010), WBSF values were below the consumer tolerance of 3.15 kg (Roeber et al., 2005; Gill et al. 2008).

A number of studies have evaluated inclusion of distillers grains (DGS) in beef finishing diets (Corrigan et al., 2008; Depenbusch et al., 2008; Haack et al., 2011); however, there are a lack of data that consider the relationship between fat content in DGS and beef quality. Fatty acid composition influenced beef quality (de Mello Jr., 2007); therefore, feeding diets with increased concentrations of polyunsaturated fatty acids (PUFA), such as those contained in DGS, can lead to beef products with altered ratios of saturated and unsaturated fatty acids (Depenbusch et al., 2009). Beef with higher PUFA concentrations will likely have increased oxidation rates, affecting color stability, rancidity, and off flavor development, thus leading to a decrease in shelf-life and consumer acceptability.

Oxidation of lipids is one of the primary causes of quality deterioration in meat. Lipid oxidation primarily targets unsaturated fatty acids; thereby leading to softening of fat. Soft fat is

undesirable as it affects product appearance and texture, especially when the product is processed. When mechanically processing meat (e.g., grinding or chopping) unsaturated fats may melt leading to fat coating on the product (Carr et al., 2005).

Previous studies have shown inconclusive effects of DGS on meat quality. Results from some studies have indicated that finishing cattle on diets containing DGS may negatively affect redness (a*) and lightness (L*) values of strip steaks in retail display (Gill et al., 2008; Leupp et al., 2009). Koger et al. (2010) found no discoloration of color of ground beef patties when cattle were fed 20% or 40% dried DGS; however, fatty acid profiles of steaks were negatively affected.
Previous studies indicate increases in PUFA in beef, specifically linoleic (C18:2) acid, when DGS was included in finishing diets (de Mello Jr., et al., 2007; Black et al., 2009; Aldai et al., 2010). Despite this, when DGS are included in the diet at 0-75% of dietary dry matter (DM), lipid oxidation was not affected for fresh steaks as indicated by thiobarbituric acid reactive substances (TBARS; Gordon et al., 2002; Gill et al., 2008; Depenbusch et al., 2009). However, increased oxidation has been observed in fresh ground beef patties when 40% dried DGS was included in the finishing diet (Koger et al., 2010).

Typically, high protein dried distillers grains (HPDDG) contains 39% to 44 % crude protein and 4% fat, compared with conventional DGS which contains approximately 25 to 30% crude protein and 10 to 14% fat. Unlike conventional dried DGS, no solubles are added to HPDDG.

Several studies have examined the effects of feeding DGS with reduced fat content on beef cattle performance and carcass characteristics (Corrigan et al., 2008; Depenbusch et al., 2008; Haack et al., 2011). However, further investigation is warranted regarding shelf-life stability and sensory

characteristics of beef from cattle fed HPDDG. Therefore, the objective of the current study was to evaluate the effect of replacing corn with 35% HPDDG on carcass characteristics, moisture loss, fabrication percentage, sensory attributes, shelf-life stability and lipid composition.

MATERIALS and METHODS

Animals, Location, and Backgrounding Phase

Care and handling of all animals used in this experiment was conducted under the approval of the University of Minnesota Institutional Animal Care and Use Committee (IACUC Protocol # 0908A71701). Purebred Angus steers (n = 48) initially weighing 230 ± 28 kg and originating from the beef cow herd at the University of Minnesota North Central Research and Outreach Center (Grand Rapids, MN) were used to evaluate the effects of partially replacing dry rolled corn (DRC) in traditional DRC-based finishing diets with 35% conventional DDGS or 35% HPDDG on feedlot performance and carcass characteristics.

All steers received vaccinations against infectious bovine rhinotracheitis virus, bovine viral diarrhea Types 1 and 2, parainfluenza$_3$, and bovine respiratory syncytial virus (Bovi-Shield® Gold FP5 VL5; Pfizer Animal Health; New York, NY) and against *Clostridium chauvoei*, *Cl. septicum*, *Cl. novyi*, *Cl. sordellii*, *Cl. perfringens* types B, C, and D, and *Cl. haemolyticum* (Ultrabac® 8; Pfizer Animal Health; New York, NY) prior to trial initiation. Seventy-five days prior to initiation of the experiment, steers were allocated into one of two pens in a facility with a Calan gate individual feeding system (American Calan, Inc.; Northwood, NH) at the North Central Research and Outreach Center. Each Calan gate had a 36.6 cm base and a 91.4 cm depth of

bunk. One concrete floor pen contained 18 steers (pen 1 dimensions were 5.18 m wide by 10.7 m long; 71.1 cm per steer of bunk space) and the other concrete floor pen contained 30 steers (pen 2 dimensions were 5.18 m wide by 9.75 m long; 63.5 cm per steer of bunk space). Average body weight (BW) of steers in both pens was equal, and each pen had continuous access to an outdoor dry lot (pen 1 dry lot was 1,769 sq. m and pen 2 dry lot was 1,415 sq. m) and an automatic water fountain (pen 1 - Mirafount E3465, 100 head capacity and pen 2 - Ritchie 300, 125 head capacity). Steers were fed a common backgrounding diet at 0700 as they began the training process to the Calan gates. The backgrounding diet contained increasing proportions of DRC and decreasing proportions of alfalfa haylage as energy concentration was increased from 1.0 to 1.2 Mcal NE_g per kg DM over a four-wk growing phase.

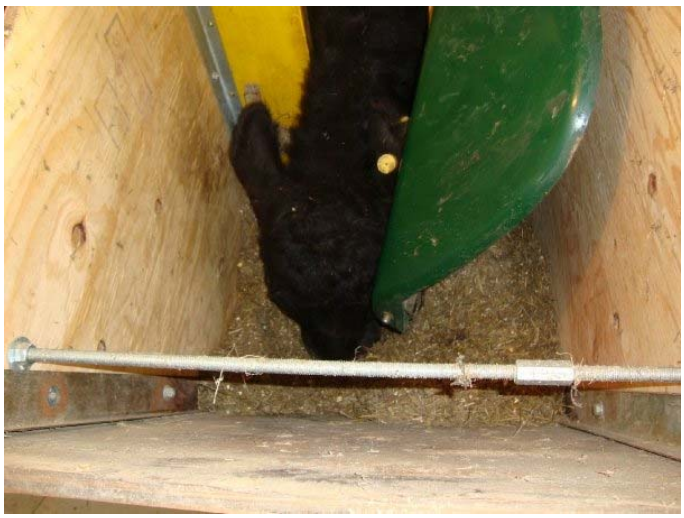
Experimental Design, Experimental Diets, and Data Collection

On d -42, steers within pen were assigned to finishing diets so that average BW was equal among all three treatment diets within and across pen and assigned randomly to individual Calan gates within pen. All steers continued to receive a common backgrounding diet until d -28 as they were trained to their assigned Calan gate. Finishing diets included (Table 1): 1) 82.5% DRC (86.9% DM, 9.5% CP, 11.6% NDF, 4.9% ADF, 64.2% starch, 3.4% fat, 85.7% TDN, and 1.41 Mcal/kg NE_g), 12.1% CP, 55% starch, 3.55% fat, 0.15% S, and 1.29 Mcal/kg NE_g, (CON); 2) 35% conventional DDGS, 51% DRC, 17.1% CP, 34% starch, 5.96% fat, 0.42% S, and 1.29 Mcal/kg NE_g, (DDGS); and 3) 35% HPDG, 51% DRC, 22.0% CP, 36% starch, 3.53% fat, 0.37% S, and 1.26 Mcal/kg NE_g, (HPDG). All diets contained 12% haylage (36.7% DM, 14.2% CP, 55.4% NDF, 36.2% ADF, 10.6% ash, 53.5% TDN, and 0.53 Mcal/kg NE_g) and were formulated to supply 300 mg monensin sodium/steer daily. Conventional DDGS (Lake Crystal, MN) and HPDDG (Glenville, MN) were sourced from POET Nutrition (Sioux Falls, SD). A single delivery of each co-product was sufficient

for the entire duration of the finishing phase. All diets were mixed as needed in large batches using a mixer truck and unloaded into individual bays located within the Calan gate facility. Batch sizes were estimated to last approximately three days to maintain diet integrity and freshness. If more than one diet was mixed on the same day, CON was mixed first followed by the HPDDG diet prior to the DDGS diet in attempt to minimize carryover of ingredients and fat between diets.

On d -28, adaptation to finishing diets began while training to the Calan gates continued, and all steers received an initial implant (Synovex® Choice; Pfizer Animal Health; New York, NY) on d -11. On d 1 of the experiment, steers were consuming the finishing diets *ad libitum*. Initial BW was a 1-d BW measurement following a 16-h period where steers were withheld from feed. Average initial BW of steers on d 1 of the experiment was 317 ± 8 kg. Steers were fed for *ad libitum* intake once daily at 0700. Prior to feeding, all steers were temporarily locked out of the Calan gate facility (approximately 90 min) and were allowed access to the facility after feed delivery was complete. Daily feed deliveries were weighed individually using a platform scale (model FE-31KA2; A&D Weighing; San Jose, CA) with attached indicator (model 100KA1; A&D Weighing; San Jose, CA), recorded, and delivered to the respective bunk. Bunks were read daily and managed as in a typical commercial feedlot employing the slick bunk approach. Daily addition or reduction in individual feed delivery did not exceed 0.22 kg. Feed refusals were measured and recorded once weekly, and a sub-sample of each refusal was collected and immediately frozen (-20°C) for subsequent DM analysis. Samples of ration ingredients and diets were collected weekly, immediately frozen (-20°C), and composited by month prior to overnight shipment to Dairyland Laboratories (St. Cloud, MN) for chemical analyses by NIR. Chemical composition values for each monthly analysis were averaged to obtain an overall mean value and standard deviation for chemical composition of each individual ingredient and treatment diet. Dry-rolled corn, alfalfa haylage, and each co-product were analyzed for

laboratory DM at 105°C (Shreve et al. 2006; NFTA method 2.1.4), CP by combustion analyzer (AOAC, 2000 method 990.03), ADF (AOAC, 1996 method 973.18), NDF (analyzed using sodium sulfite and amylase, Van Soest et al., 1991), acid detergent insoluble CP (AOAC, 1996 method 973.18), soluble CP (AOAC, 2000 method 990.03), crude fat (AOAC, 2000 method 920.39), ash (AOAC, 1996 method 942.05), minerals (Ca, P, Mg, K, and S; AOAC, 2000 method 985.01), and TDN and NE_g (using OARDC equations). Treatment diets were analyzed for laboratory DM at 105°C (Shreve et al. 2006; NFTA method 2.1.4), CP by combustion analyzer (AOAC, 2000 method 990.03), ADF (AOAC, 1996 method 973.18), NDF (analyzed using sodium sulfite and amylase, Van Soest et al., 1991), lignin (AOAC, 1996 method 973.18), acid detergent insoluble CP (AOAC, 1996 method 973.18), soluble CP (AOAC, 2000 method 990.03), starch (Bach Knudsen, 1997), crude fat (AOAC, 2000 method 920.39), ash (AOAC, 1996 method 942.05), minerals (Ca, P, Mg, K, S, Na, and Cl; AOAC, 2000 method 985.01), and TDN and NE_g (using OARDC equations). Diet ingredient proportions were adjusted accordingly if percent DM changed for alfalfa haylage or DRC to maintain formulated diet composition on a DM-basis. Weekly diet refusal samples were dried for 48 h in a 60°C forced-air oven (model DC-246-E; Blue M Electric, Watertown, WI) at the ruminant nutrition lab (University of Minnesota, St. Paul, MN) to determine DM to correct for actual steer daily DMI.



Steers were weighed every 28-d prior to the morning feeding using a For-Most portable squeeze chute (For-Most Livestock Equipment; Hawarden, IA) equipped with a Tru-Test scale (Tru-

Test, Inc.; Mineral Wells, TX). On d 56, all steers received a terminal implant (Synovex® Choice; Pfizer Animal Health; New York, NY).

Carcass Data Collection

After 118 d on feed, steers were transported in one group approximately 485 km to a commercial abattoir (PM Beef Holding, LLC; Windom, MN). Hot carcass weight was divided by common group dressing percentage (60.9%) to calculate adjusted final live BW. Dressing percent was determined by: dividing HCW by live final BW.

Hot carcass weight and cold carcass weight (CCW), 12th rib back fat, percent kidney pelvic heart fat (KPH) and REA were collected by University of Minnesota personnel 48 -h postmortem. Marbling score, USDA Yield Grade and Quality Grade were evaluated by a USDA grader.

Fresh Beef Fabrication and Collection

Fresh beef products were fabricated according to Institutional Meat Purchasing Specifications (IMPS). Strip loins (IMPS #180), shoulder clods (IMPS #114), and inside rounds (IMPS #169) were removed 52 -h postmortem from the right side of the carcass, and individually identified using carcass identification tags cross-referenced to animal identification tags during harvest. Strip loins, shoulder clods, and inside rounds 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 and inside rounds were placed in a blast freezer (-20° C) until further evaluation.

Strip Loin Sample Preparation

Strip loins were faced perpendicular to the length of the loin, and steaks were serially cut, 2.54 -cm thick, from the anterior end of each strip loin. The first steak was designated for drip loss analysis. The second and third steaks were placed on a polystyrene tray and overwrapped with poly-vinyl chloride film with an oxygen transmission rate of 1400 cc/m^2, and placed in simulated retail display for pigment and lipid oxidation analysis. The fourth, fifth, and sixth steaks were vacuum-packaged, frozen (-20°C) and designated for sensory evaluation, while the seventh and eighth steaks were designated for Warner-Bratzler shear force testing. The remaining portion of the strip loin was vacuum-packaged and frozen at -20° C for further analyses.

Inside Round Preparation

Inside rounds (approximately 9 kg) were thawed (vacuum packaged) at 4° C for 3 d. Entire, untrimmed inside rounds were ground twice (Biro Grinder, Model 346; Marble Head, OH) with a 0.375 cm plate. Fresh ground beef (approximately 0.91 kg) was placed on polystyrene trays and overwrapped with poly-vinyl chloride film with an oxygen transmission rate of 1400 cc/m^2 and placed in simulated retail display. Fresh ground beef (approximately 0.23 kg) was vacuum packaged and placed in a blast freezer (-20° C) for subsequent analysis of pre-display thiobarbituric acid reactive substance (TBARS). At the end of retail display (6 d), trays were vacuum packaged for post-display TBARS analysis in the same manner as described previously.

Shoulder Clod Preparation

Shoulder clods, (approximately 9.5 kg) were thawed (vacuum-packaged) at 4° C for 3 d. Entire, untrimmed shoulder clods were ground twice (Biro Grinder, Model 346; Marble Head, OH) with a 0.375 cm plate. Randomly blended meat blocks (4 animals/treatment, total of 3 blocks per treatment) were divided into two batches (approximately 9.1 kg) one for summer sausage and one for bologna fabrication.

For summer sausage, 1 batch of blended ground beef was mixed with a commercial blended seasoning mix (Summer Sausage Seasoning #769025, Nassau Foods; Minnetonka, MN) and culture, (TRU MARK Formula-100, TRU MARK INC; Linden NJ), and stuffed with an automatic stuffer (Handtmann , Model VF-608; Biberach, Germany) into mahogany fibrous casings (10.8 cm; Walsrober Casings; Mar/Co Sales, Burnsville, MN). Stuffed sausages were fermented, smoked with liquid smoke (Charsol C-10, Manitowoc, WI), and cooked in an Enviro-Pak smokehouse (Model CVU 500E –IT, Portland, Oregon) to an internal temperature of 71° C, and chilled to 4 °C. Cooked sausage was sliced using a Globe Slicer (Model 400, Stamford, Connecticut) to a thickness of 9.52 mm.

For bologna production the second blended meat block from shoulder clods was chopped (speed setting 2, 3 knife head with Alpina tangential form blades) for 90 minutes using an Alipina bowl chopper (Model PB 80-890-II; Koch, Kansas City, MO) with seasoning (Bologna SCTP, Newly Weds Foods; Minneapolis, MN) and 2.27 kg of ice (0° C) and stuffed into clear fibrous casings (6.35 cm; Walsrober Casings; Mar/Co Sales, Burnsville, MN), cooked and smoked with liquid smoke to an internal temperature of 71° C, chilled (4° C) and sliced (Globe Slicer, Model 400, Stamford, Connecticut; 9.52 mm thick).

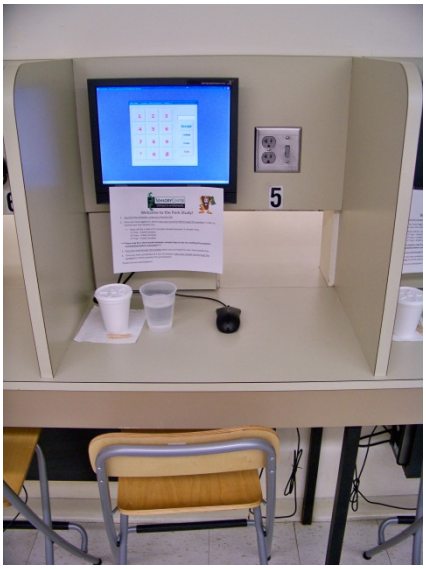
Moisture Loss

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 and final weight (unpacked and patted dry) divided by the initial weight multiplied by 100. Vacuum-packaged purge loss of the inside round, 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. Fabrication percentage of the inside round, strip loin and shoulder clod was calculated as the product weight divided by the cold carcass weight multiplied by 100.

Sensory Analysis

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 108 untrained consumer panelists. All panelists were 18 years of age or older, had no food allergies, and consumed steak at least twice per month, and consumed summer sausage within the previous 6 months. 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 1cm x 1cm x 2.54 cm cubes and placed in the top part of double boilers

containing sand in the bottom heated to ~82° C (replaced every h). 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 panelists in three sets of three samples each. The first set corresponded to replicate 1, the second set corresponded to replicate 2, and the third set corresponded to replicate 3. Each set was balanced for order and carryover effects.

One hundred- one panelists were recruited for sensory evaluation of summer sausage in the same manner as described for steak consumer sensory evaluation. Slices of summer sausage (0.3 cm thickness and 6.4 cm diameter) were quartered and 2 quarters were served to panelists in a lidded 60 ml plastic soufflé cup coded with random 3-digit numbers for evaluation. Sample replications were served in the same manner as described for steaks consumer sensory evaluation.

Panelists were instructed to eat one piece and rate it for overall liking, flavor liking, and texture liking on 120-point labeled affective magnitude scales, with the left-most end labeled *greatest imaginable disliking* and the right-most end labeled *greatest imaginable liking* for steak and summer sausage. Panelists were then instructed to eat the second piece and rate it for off-flavor, juiciness (steak), sourness (summer sausage), and toughness ratings on a 20-point line scale, with the left most end labeled *none* and the right most end labeled *extremely intense* for all treatments and replications.

Warner-Bratzler Shear Force (WBSF)

Duplicate steaks were thawed for 24 h at 4° C, individually wrapped in aluminum foil, and cooked at 180º C, using a Frigidaire® kitchen oven (Dublin, OH) 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 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 perpendicular to the length of the fiber using a Warner-Bratzler testing machine (G-R Electric; Manhattan, KS). Six cores were sheared per steak to represent the entire surface of the *longissimus dorsi.*

Simulated Retail Display

All products designated for simulated retail display were randomly placed in a remote coffin case, 1.1 m x 2.54 m x 0.86 m high (Hussmann, GF-8, AA Equipment Company, Inc., Minneapolis MN) maintained at 4° C under cool white fluorescent lighting (Sylvania H9b8, 110W; 2,640 lux). Beginning at 0 h, each product was evaluated for objective and subjective color characteristics every 24 h for the duration of the study. Steaks were evaluated for 6 d, ground beef for 5 d, summer sausage for 14 d, and bologna for 13 d.

Objective Color Evaluation

Objective color of each product was instrumentally measured using a HunterLab Miniscan XE Plus spectrophotometer (HunterLab Associates Inc., Reston, VA) equipped with a 6 mm aperture and a D65, 10° illuminant. The colorimeter was calibrated daily prior to evaluation using pre-overwrapped (PVC) black glass and white ceramic titles provided by the manufacturer. Color coordinates were recorded for L*(psychometric lightness; black=0, white=100), a* (absolute red =100; absolute green= -100) and b* (absolute yellow=100; absolute blue= -100) following procedures of the Commission Internationale de I'Eclairage (CIE, 1976) and American Meat Science Association (AMSA, 1991). Objective color measures were obtained each day by averaging readings (3 readings per steak; 2 steaks/package) at various locations on the surface of the Longissimus dorsi for a total of 6 readings per animal per day.

Objective color measurements for ground beef were obtained each d by averaging 6 readings per package (1 package/treatment) of ground beef at various locations on the surface of the product. Objective color measurements for summer sausage were obtained each day by averaging 1 reading per slice of summer sausage (6 slices/package; 3 packages/treatment). Color measurements for bologna were obtained each d by averaging 3 readings for each slice of bologna, for a total of 9 readings (3 slices/per treatment).

Subjective Color Evaluation

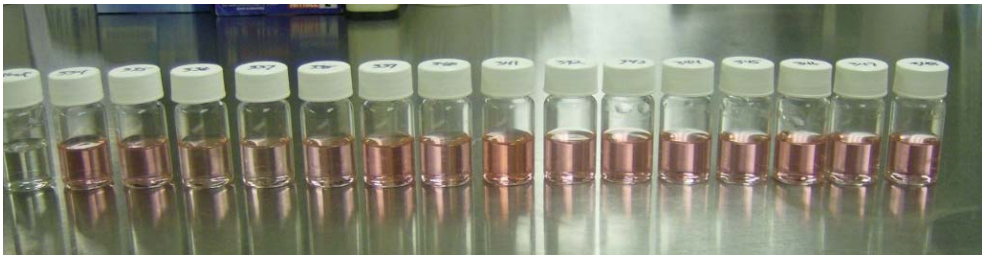
A trained panel consisting of University of Minnesota personnel, staff and faculty subjectively evaluated products under retail display. There were 8 panelists for steaks, 9 panelists for ground beef, 8 panelists for summer sausage and 7 panelists for bologna. Parameters evaluated were lean color (8 point scale), surface discoloration (11 point scale) and overall acceptability (8 point scale). Surface discoloration was characterized as 1 = complete [91-100%] discoloration; 11 = no [0%] discoloration and overall color was characterized as 1 = extremely undesirable; 8 = extremely desirable. For strip steaks and ground beef, lean color was characterized as 1 = extremely brown; 8 = extremely bright, cherry red. For summer sausage and bologna lean color was characterized as 1 = extremely brown; 8 = extremely bright, pink.

Lipid Analyses

For fatty acids, total lipid was extracted following AOCS Ce 2-66, and AOCS Ce 1-62 procedures (AOCS, 1998). Approximately 0.25 g of melted fat from subcutaneous dorsal trim was weighed for extraction of lipid. For conversion of lipids to fatty acid methyl esters, approximately 7 ml of 0.5 N methanolic sodium hydroxide and a glass bead were added to the melted fat sample. Samples were refluxed for 10 min and approximately 5 mL of 14% boron trifluoride methanol solution was added and allowed to reflux for another 2 min. Then, 10 ml of heptane was added and allowed to flux for an additional minute. After separation of the fatty acid methyl esters, samples were analyzed by gas chromatography (Hewlett-Packard 6890 Plus Gas Chromatograph, Agilent; Santa Clara, CA). Fatty acids were identified by comparison of retention times with known standards; GLC- 08A, 60, 67, 80, 90, and 546B (Nu-Chek, Elysian, MN). Total saturated fatty acid (SFA), monounsaturated fatty acid (MUFA), and PUFA were determined by summing the respective classes of fatty acids. The total amount of unsaturated fatty acids (UFA) was determined by summing MUFA and PUFA. Iodine

values (IV) for back fat were calculated as: IV = C16:1(0.95) + C18:1(0.86) + C18:2(1.732) + C18:3(2.616) + C20:1(0.785) + C22:1(0.723) as described by AOCS Cd 1c-85 (1998).

Lipid oxidation was measured by the thiobarbituric acid assay (TBA) according to the protocol of Tarladgis, Watts, Younathan, & Dungan, (1960) at 0 and 6 d of display. Ground beef (10 g) was blended (Waring commercial laboratory blender, 57BL30; New Hartford, CT), with 50 ml of distilled water for 1 min. Blender was rinsed with 47.5 ml of distilled water, 2.5 ml of hydrochloric acid (1:2), and 3-4 drops of antifoam (1520-US, Dow Corning®; Midland, MI) were added to the flask. The contents of the flask were then distilled at approximately 99.4º C. The distillate was collected in a beaker until it reached approximately 50 ml. The distillate was mixed, and then 5 ml of the distillate was pipetted into 5 ml of TBA (0.002M) and mixed well. Samples were then immersed into a water bath at 95º C for 35 min. Vials (20ml; VWR Trace clean; West Chester, PA) were then cooled to room temperature by immersing them in 25º C water for 5 min. The spectrophotometer (Spectronic 20+, Spectronic Instruments, Inc; Rochester, NY) was set to a wavelength control of 532 nm, and a filter level of 340-599 nm. Wavelength and absorbance values were recorded at 532 nm. The absorbance value was multiplied by 7.8 to calculate TBARS concentration (ppm).



Statistical Analyses

Live Performance

Live steer performance and carcass characteristics were analyzed using the MIXED procedure of SAS (SAS 9.2, SAS Institute, Inc. Cary, NC). Experimental unit was steer. Fixed model effect was treatment and random effect was pen. The linear model for these analyses is written as follows:

$$y_{ij} = \mu + \beta_i + \alpha_j + \varepsilon_{ij}$$

where, y_{ij} represents observation$_{ij}$; μ represents the overall mean; β_i represents the random effect of pen$_i$; and α_j represents the fixed effect of treatment$_j$. The residual term ε_{ij} is assumed to be normally, independently, and identically distributed with variance σ^2_e.

Carcass and Meat Quality

Statistical analysis for USDA Quality and Yield Grade categorical data was performed using the GENMOD procedure of SAS (SAS Inst., Inc, Cary, NC). Steer was the experimental unit and the model included dietary treatment as the fixed effect. Type 3 fixed effects were used to determine significance ($P < 0.05$) or trends ($P < 0.10$) among treatments. The PDIFF option was used to separate least squares means when a significant *F*-test statistic was present. Treatment means are presented as least squared means, and weighted standard errors were calculated as: Σ(error*degrees of freedom)/Σ(total degrees of freedom) and subset contrasts analyzed were: 1) CON vs. distillers grains-containing treatments.

Mixed model analysis of variance (PROC MIXED procedure of SAS) was used to analyze hot and cold carcass weight, 12th rib back fat, KPH, REA, drip loss, purge loss, fabrication loss, WBSF, TBARS and fatty acid analysis. The Restricted Maximum Likelihood (REML) procedure was used to estimate the variance components and the Kenward-Rogers procedure was used to determine degrees of freedom approximation. Steer was the experimental unit and the statistical model included dietary treatment as the fixed effect. For those variables considered significant ($P < 0.05$), mean separations were performed using the PDIFF functions of SAS. Weighted standard errors were calculated as: Σ(error*degrees of freedom)/Σ(total degrees of freedom) and subset contrasts analyzed were: 1) CON vs. distillers grains-containing treatments 2) HPDDG vs. DDGS.

For sensory analysis, the PROC MIXED procedure of SAS was used to determine if samples differed in any of the attributes. Overall liking, flavor liking, texture liking, off flavor, toughness, juiciness (steaks), and sourness (summer sausage) were dependent variables and product, replicate and product*replicate were predictors. Subject and subject*product were random predictors in the models. Bonferonni correction was used to determine if specific differences among samples were significant. Subset contrasts analyzed were: 1) CON vs. distillers grains-containing treatments.

For procedures involving repeated measures (subjective and objective color measurements), the model included fixed effects of time of determination and the interaction between dietary treatment and time on display. For all retail display variables, each variable analyzed was subjected to five covariance structures: compound symmetry, autoregressive of order one (AR(1)), toeplitz, unstructured, and spatial power. The covariance structure that yielded the smallest Akaike information criterion (AIC) and Bayesian information criterion (BIC) coefficients indicated best model fitting when the AR(1) covariance matrix was used. Subset contrasts analyzed were: 1) CON vs. distillers grains-containing treatments and 2). HPDDG vs. DDGS.

RESULTS AND DISCUSSION

Chemical and Energy Composition of Corn Milling Co-Products and Experimental Diets

Chemical and energy composition (DM-basis) of traditional DDGS and HPDDG co-products analyzed by Dairyland Laboratories are reported in Table 1. The reported chemical and energy values are the average of four monthly analyses derived from composites of four weekly samples. The objective of the experiment was to replace portions of DRC in finishing diets with either co-product; therefore, diets were not formulated to be isonitrogenous or isocaloric. As expected, the CP concentration of HPDDG was much higher (39.0%) than conventional DDGS (27.6%), and fat concentration of HPDDG was lower (5.1%) than conventional DDGS (10.9%). The CP and fat

concentrations for HPDG used in this experiment were lower and higher, respectively, than CP and fat concentrations reported by others (Depenbusch et al., 2008) for similar corn milling co-products. Sulfur concentration was lower (0.69%) for HPDDG compared to conventional DDGS (0.84%). As dietary inclusion concentration of HPDDG increases in finishing cattle diets, there will be lower total dietary intake of fat and S, which may promote performance advantages in feedlot cattle when feeding similar inclusion concentrations of HPDDG and conventional DDGS.

Concentrations of TDN and NE_g in HPDDG were lower (76.7% and 1.32 Mcal/kg) than concentrations in conventional DDGS (82.2% and 1.40 Mcal/kg) likely due to its lower fat concentration. Lower fat concentration may reduce feeding value of HPDDG compared to DDGS (Bremer et al., 2011*b*) as well as reduce energy concentrations of diets containing similar inclusion concentrations of these corn milling co-products (Gigax et al., 2011). Chemical and energy composition (DM-basis) of experimental diets are reported in Table 2. The reported chemical and energy values are the average of four monthly analyses derived from composites of four weekly diet samples. Compared to CON not containing distillers grains co-products (12.1% CP), the DDGS diet contained 17.1% CP while the HPDDG diet contained 22.0% CP due to differences in co-product CP composition. As expected, the HPDDG diet contained lower concentration of fat (3.53%) compared to DDGS (5.96%) but was comparable to the fat concentration of CON (3.55%). Compared to a similar feedlot experiment conducted by Gigax et al. (2011), dietary fat concentrations of diets containing 35% conventional WDGS (6.91% dietary fat) or low fat WDGS (4.72% dietary fat) were greater than fat concentrations of diets fed in the current experiment due to greater fat concentrations of each WDGS. Lower TDN and NE_g concentrations of the HPDDG diet (75.7% and 1.26 Mcal/kg) compared to CON (79.9% and 1.29 Mcal/kg) and DDGS (77.2% and 1.29 Mcal/kg) diets were likely a result of the lower fat concentration in the HPDDG diet (Bremer et al., 2011*b*). When NE_g concentrations of treatment

diets were calculated using NRC (1996) equations based on actual steer intake and BW gain during finishing, dietary NE_g concentrations were higher than NE_g concentrations calculated using OARDC equations (based on diet ADF and digestibility estimates) and averaged 1.45, 1.47, and 1.48 Mcal/kg for CON, DDGS, and HPDDG, respectively. Due to differences in S concentration of each co-product fed in the current experiment, dietary S concentrations averaged 0.15, 0.42, and 0.37% S for CON, DDGS, and HPDDG. Dietary S concentrations of all diets met minimum dietary S requirements (0.15% S), but S concentrations of the DDGS and HPDDG diets were greater than the maximum tolerable S concentration (0.30% S) for high-concentrate diets (NRC, 2005). However, the S concentrations of the DDGS and HPDDG diets did not exceed the 0.46% threshold concentration reported by Vanness et al. (2009*c*) for risk of polioencephalomalacia in feedlot cattle consuming finishing diets containing high concentrations of corn milling co-products.

Feedlot Steer Live Performance

Results for live steer feedlot performance are listed in Table 3. Initial BW was similar (P = 0.90) across all treatments and averaged 317 ± 8 kg. Final live BW was not different (P = 0.54) and averaged 553, 552, and 540 ± 9 kg for CON, DDGS, and HPDDG. Overall BW gain for the finishing period was similar (P = 0.49) and averaged 234, 235, and 226 ± 6 kg for CON, DDGS, and HPDDG. In contrast, Gigax et al. (2011) reported crossbred yearling steers had heavier final live BW when finished with a diet containing 35% conventional WDGS (12.9% fat) compared to steers finished with a traditional corn-based diet or a diet containing 35% low-fat WDGS (6.7% fat). Similar to the current experiment, Depenbusch et al. (2008) reported similar final live BW for heifers consuming a finishing diet containing 13.5% HPDDG (4% fat) compared to heifers consuming a traditional steam flaked corn (SFC) based diet or a diet containing 12.9% conventional DDGS (12% fat).

Overall DMI tended ($P = 0.08$) to be greater for CON compared to HPDDG (10.3 vs. 9.7 kg/d) but DMI for CON was similar ($P = 0.58$) to DDGS (10.2 kg/d). This observation is in contrast to Depenbusch et al. (2008), who reported similar DMI in heifers consuming the control (traditional SFC-based diet) and either diet containing 12.9% conventional DDGS or 13.5% HPDDG. Gigax et al. (2011) also reported similar DMI between yearling steers consuming corn-based control and low-fat WDGS finishing diets. In the current experiment, DMI from d 28 through finishing was greater ($P < 0.01$) for CON than HPDDG (10.8 vs. 9.9 kg/d), but DMI for CON was similar ($P = 0.16$) to DDGS (10.5 kg/d). However, DMI from d 28 through finishing tended to be greater ($P = 0.07$) for DDGS than HPDDG. In the current study, it is unclear why differences in DMI were observed. Depenbusch et al. (2008) reported greater DMI in feedlot heifers consuming 12.9% conventional DDGS compared to heifers consuming 13.5% HPDDG in traditional SFC-based finishing diets. However, 0.7% urea was added to the conventional DDGS diet but was not added to the diet containing HPDDG. Thus, Depenbusch et al. (2008) speculated the diet containing HPDDG may have been deficient in DIP and thus limited intake due to reduced microbial fermentation. Urea was not included in any of the treatment diets in the current experiment; therefore, it is difficult to speculate whether differences in DMI could be attributed to a deficiency in DIP. Likely, the tendency for increased DMI from d 28 through finishing in steers consuming DDGS compared to HPDDG is related to possible improved diet palatability with inclusion of 35% conventional DDGS.

Overall ADG was similar ($P = 0.49$) among treatments and averaged 1.98, 1.99, and 1.91 ± 0.05 kg for CON, DDGS, and HPDDG. Average daily gain from d 28 through end of finishing was also similar ($P = 0.44$) across treatments and averaged 2.20, 2.13, and 2.09 ± 0.06 kg for CON, DDGS, and HPDDG. Depenbusch et al. (2008) also reported similar ADG among all heifers, but these observations are in contrast to Gigax et al. (2011). Gigax et al. (2011) reported yearling steers

consuming a diet containing 35% conventional WDGS gained 0.3 kg BW more per day than yearling steers consuming a control diet or a diet containing 35% low-fat WDGS, even though DMI was similar across all treatments. However, steers consuming the low-fat WDGS had similar ADG to steers consuming the control diet (Gigax et al., 2011). In agreement with Depenbusch et al. (2008), overall G:F was not different ($P = 0.68$) among treatments in the current study and averaged 0.192, 0.196, and 0.197 ± 0.004 for CON, DDGS, and HPDG. Gigax et al. (2011) also reported similar G:F among steers consuming traditional corn-based and low-fat WDGS finishing diets. Additionally, G:F from d 28 through the end of finishing was similar ($P = 0.62$) across all treatments and averaged 0.203, 0.205, and 0.210 ± 0.005 for CON, DDGS, and HPDDG, even though DMI differed across treatments during this phase.

Carcass Characteristics and Moisture Loss

Treatment had no effect on dressing percentage (P = 0.22) hot carcass weight (P = 0.54), 12th rib backfat (P = 0.18), and percentage of kidney, pelvic, heart fat (P = 0.35; Table 4). Gigax et al., (2011) reported that steers fed 35% WDGS (12.9% fat) had heavier HCW as compared to those fed 35% WDGS containing half as much fat (6.7%); HCW of steers fed 35% WDGS (12.9%) was also greater than that of steers fed a high moisture corn (HMC)/ dry rolled corn (DRC) control. They also reported no difference in marbling score, 12th rib back fat, and REA between treatments. Similarly, REA was not different (P = 0.57) for steers in the current study, and averaged 78.1 cm^2 for all treatments. Average USDA Yield Grades were not different (P = 0.54) for CON, DDGS, and HPDDG (2.6, 2.8, and 2.7, respectively). Treatment had no effect on USDA Quality Grade (P = 0.51); an average of 81% of carcasses graded USDA Choice. Treatment did not (P=0.26) affect marbling scores. Average marbling score was 588 across treatments. Depenbusch et al (2008) also found no

difference in carcass characteristics for heifers when adding a fractionated DGS product containing 4% fat to a steam flaked corn-based diet.

Fabrication loss did not differ across treatments for the inside round (P = 0.20), strip loin (P = 0.36), and shoulder clod (P = 0.20; Table 5). Mean drip and purge losses were not different across treatments (P = 0.49 and 0.16, respectively; Table 5).

Sensory Characteristics

Treatment did not affect consumer sensory scores for overall liking (P = 0.10), flavor liking (P = 0.06), or texture liking (P = 0.47), among steaks (Table 6). Although there were no differences for juiciness, steaks from HPDDG steers tended (P=0.10) to be rated highest for juiciness (8.49) while those from CON steers were rated the lowest (7.72). Leupp et al. (2009) reported no differences in tenderness, juiciness and flavor in steaks from steers fed 30% DDG in the finishing diet. In that study, juiciness was numerically the highest rated in steaks from steers fed 30% DDG. Similar to results from the current study, Haack et al (2011) found no differences in beef flavor intensity and juiciness of cattle fed WDGS containing various contents. Haack et al (2011) also found that beef from steers fed control and 4.72% fat WDG was less tender, with less prevalent off -flavors than that from steers fed 6.91% fat WDGS. In the current study, we observed no difference in tenderness or off-flavor of beef steaks from steers fed low and standard fat DGS.

No data exists on the effect of feeding DGS in finishing diets on cooked and fermented sausage. For summer sausage, CON was rated highest for overall liking (70.0; P = 0.01) and flavor liking (70.6; P = 0.04), while sausages from DDGS steers was rated the lowest (66.3 and 67.4, respectively; Table 6). Sausage from steers fed CON and HPDDG was rated higher than that from steers fed DDGS for texture liking; however, as fat level in diets decreased (5.96, 3.55 and 3.53 %;

DDGS, CON and HPDDG, respectively) summer sausage was rated tougher ($P < 0.001$). Similarly, results from a study evaluating fermented summer sausage from pork where pigs were fed various concentrations of oleic acid demonstrated a decrease in sensory scores for texture with increasing oleic acid inclusion. When tasting pork sausage from higher oil treatments, panelists reported that the summer sausage was mushier ($P < 0.05$), yet, consumer preference is for a firmer summer sausage (Shackelford, Miller, Haydon, & Reagan, 1990).

Warner Bratzler Shear Force

Warner-Bratzler Shear Force values did not differ among treatments ($P=0.25$; Table 6). Similar results were reported by Aldai et al. (2010) and Koger et al. (2010) when evaluating corn and wheat WDGS and DDGS at 20 to 40% in the diet. Results from WBSF in the current study were supported by the consumer panel results, which indicated that treatment had no effect on toughness ($P=0.17$) of strip steaks. Shackelford, Morgan, Cross, & Savell, (1991) reported that the U.S. consumer threshold for slightly tender beef steak ranged between 3.9 and 4.6 kg of shear force. In the current study, mean shear force values were 2.60 ± 0.22 kg. Research with corn DGS and sorghum DGS also showed WBSF values below the consumer threshold for strip steaks (Roeber et al., 2005; Gill et al., 2008).

Objective and Subjective Color Evaluation

Fresh Beef

For strip steak retail evaluation, treatment did not affect overall L* or b* values ($P = 0.87$ and 0.43, respectively; Table 7). However, treatment did affect overall mean a* values ($P <0.001$). Steaks from HPDDG and DDGS had lower a* values than those from CON from d 4 until the end of retail display (Figure 1). These results are supported by Haack et al. (2011) who reported that steaks from steers fed a high-moisture corn/dry rolled corn control were significantly redder throughout retail

display than those from steers fed WDGS (6.91 % fat) and WDG (4.72 % fat), while a* values of steaks from cattle fed 4.72% dietary fat WDG declined at a faster rate and to a greater degree.

Treatment had an effect on subjective lean color, overall appearance and surface discoloration ($P < 0.001$, for all attributes; Table 7). Similar to results reported for objective color, subjective lean color and overall appearance decreased while surface discoloration increased for DDGS and HPDDG steaks on d 5 of display. There was a greater reduction in lean color ($P=0.02$) for HPDDG steaks than for DDGS steaks starting on d 5 (Figure 2). Haack et al. (2011) reported that percentage discoloration significantly increased on d 5 of retail display and was strongly correlated to the decline in objective color scores of fresh steaks. Visual appearance of fresh meat has the greatest effect on a consumer's purchasing decision (Carpenter, Cornforth, & Whittier, 2001). An overall appearance score of 3 typically reflects the time when meat is discounted at the retail counter (Roeber, Gill, & DiCostanzo, 2005). Overall appearance of HPDDG and DDGS steaks were moderately undesirable (score of 3) at day 7 and 8 of display, respectively, while CON was not moderately undesirable until d 10 (Figure 3).

Treatment had no effect on ground beef L* ($P = 0.15$), a* ($P = 0.16$), or b* ($P = 0.23$) values (Table 8) over the length of display (6 d). However, on d 1 DDGS ground beef was redder ($P = 0.02$) than CON while HPDDG was similar to both treatments ($P = 0.33$ and 0.19; Figure 4). Despite this, on d 2-4, a* values of HPDDG ground beef declined at a faster rate than CON and DDGS was similar to both (Figure 4). CON ground beef had higher L* values than HPDDG on d 3, while DDGS was not different from either treatment (Figure 5).

Results from the current study are similar to those of previous research on effects of DDGS on L*, a*, and b* values of strip steaks (Gill, et al., 2008; Leupp, et al., 2009)and ground beef (Koger, et al., 2010; Roeber, et al., 2005) from cattle fed a traditional DDGS and corn-based control. When myoglobin is oxidized to metmyoglobin, adverse effect on color can be observed (Gray, Gomaa, &

Buckley, 1996). Lipid and myoglobin oxidation are closely associated, therefore propagation of oxidation by increase in PUFA content in beef from DDGS in the diet appears to reduce color stability during retail display.

Similar to steaks, lean color (P = 0.001), overall appearance (P = 0.001) and surface discoloration (P = 0.001) of ground beef were different among treatments (Table 8). Control ground beef had a more desirable lean color (P = 0.001; Figure 6) and overall appearance (P = 0.001; Figure 7) than DDGS and HPDDG. All treatments were moderately unacceptable at d 3 of retail0 display for ground beef.

Processed Beef

Overall L*, a*, or b* values of bologna (P = 0.51, 0.55, and 0.96 respectively; Table 9) and summer sausage (P = 0.23, 0.28, and 0.57, respectively; Table 10) were not affected by diet over the entire length of retail display. The CON bologna had higher L* value than HPDDG bologna (P = 0.002) or DDGS bologna (P = 0.04) on d 8 of retail display (Figure 8). Similarly on d 7, CON summer sausage (P = 0.001) and HPDDG (P = 0.001) had higher L* value than DDGS (Figure 9).

When different concentrations of oleic acid were fed in swine diets (Shackelford, Miller, Haydon, & Reagan, 1990), L*, a* or b* values of fermented summer sausage was not affected, but all color values decreased over display time. Results from another study evaluating varying fat levels in the bologna indicated no difference in objective color values between the varying levels of fat within the bologna (Carballo, Mota, Barreto, & Colmenero, 1995). It is important to note that color of processed meat products, especially an emulsion type sausage, can be influenced by fat content, added water and the pigment of the meat block before processing, among other factors. Carballo et al. (1995) noted that although there was no significant difference in color values, lower fat levels (increased water content) can lead to higher a* values and lower L* values.

Treatment affected bologna subjective lean color (P = 0.05; Figure 10), overall appearance (P = 0.03; Figure 11) and surface discoloration (P = 0.01; Figure 12). Overall appearance and surface discoloration of DDGS and HPDDG bologna was less desirable (P = 0.03) than CON (Table 9).

There was no effect of treatment on lean color (P = 0.44), surface discoloration (P = 0.16) and overall appearance (P = 0.82) of summer sausage (Table 10). Shackelford et al. (1990) found no difference in summer sausage visual panel scores for color and discoloration when comparing different levels of oleic acid in pork summer sausage.

Fatty Acid Analysis

Total fatty acids concentrations were not affected by treatment (P = 0.32; Table 11). Treatment had no effect on SFA and MUFA percentage (P = 0.44 and 0.86 respectively); however, treatment did affect PUFA (P < 0.001), with CON having lower concentrations compared to DDGS and HPDDG. Fatty acid composition of DDGS influenced beef quality (de Mello Jr., et al., 2007); therefore, feeding DDGS, which has a higher concentrations of lipid and greater fat digestibility than corn, can lead to increased lipid oxidation (Vander Pol, Greenquist, Erickson, Klopfenstein, & Robb, 2008).

Palmitic acid (C16:0) was highest (P <0.001) for fat samples from HPDDG and CON diet and lowest for the DDGS diet, while values of C18:0 (stearic acid) were highest (P=0.01) for DDGS. Gill et al. (2008) also reported greater concentrations of stearic acid in steaks from steers fed DGS than steers fed a steam-flaked corn diet with no DGS.

There was no difference among treatment (P = 0.75) in concentration of C18:1; however, concentrations of C18:2 and C18:3, major components of the PUFA group, were higher (P <0.001 and 0.04, respectively) in DDGS and HPDDG fat samples as compared to those from CON. These results are similar to those obtained de Mello Junior, et al. (2007) and Black et al. (2009), who documented greater concentrations of C18:0 and C18:2 when WDGS and DDGS were added to the diet. These

changes are small but contribute to greater total PUFA concentrations in beef from DGS treatments. Polyunsaturated fatty acid concentrations were substantially higher for beef from DDGS and HPDDG steers ($P < 0.001$) as compared to CON, contributing to a greater PUFA:SFA ratio. Haack et al (2011) reported greater concentration of C18:2, with 4.72% fat WDGS diet having a higher amount compared to 6.91% WDG diet. In the current study, although HPDDG diet contained less fat (5.1% vs 10.9%), the fatty acid profile of the two DGS was not different (Table 12). A possible explanation for the observed effects on lipid composition in the beef is that fats from the HPDDG are protected in the rumen from biohydrogenation. The solubles added back to the DDGS distillers grains are readily hydrogenated in the rumen, while fat from the HPDDG distillers is contained within the feed grain particles, possibly protecting it from biohydrogenation (Doreau & Ferlay, 1995; Zinn, Gulati, Plascencia, & Salinas, 2000). Acidic ruminal pH has a negative effect on lipolytic rumen bacteria (hungate). This may support the observation that beef from HPDDG steers in the current study had a decreased shelf-life as compared to DDGS and CON.

Calculated iodine values (IV) were higher for beef from DDGS and HPDDG steers than CON ($P = 0.01$; Table 11). Higher IV indicates a higher degree of unsaturation, which may lead to greater lipid oxidation.

Thiobarbutoric Reactive Acid Substance (TBARS)

Lipid oxidation as measured by TBARS (mg malonaldehyde/kg) indicated no difference between treatments on d 0 ($P = 0.50$; Figure 13); however, differences between treatments on d 7 ($P < 0.001$). Lipid oxidation was greater for ground beef from HPDDG and DDGS steers as compared to that from CON ($P = 0.001$). However, TBARS values were two times greater for HPDDG than DDGS (Figure 13). Similar results were reported by Haack et al. (2011) who reported higher TBARS values

for 4.72% dietary fat WDG than 6.91% dietary fat WDGS, both of which were higher than the control. Lipid oxidation is a primary factor in meat quality deterioration (Gray, et al., 1996).

CONCLUSION

Finishing beef cattle with diets containing HPDDG tended to reduce overall DMI; however, this co-product may successfully replace up to 35% of DRC or conventional DDGS in feedlot diets as there were no deleterious effects on other live performance variables or carcass characteristics. Although the analyzed energy concentration of the HPDDG co-product was lower than conventional DDGS due to its reduced fat concentration, it appears this co-product was able to provide energy and nutrients necessary to maintain similar performance and carcass characteristics as steers finished with traditional DRC-based diets or with diets containing similar levels of conventional DDGS. Although feeding HPDDG may benefit feedlot producers, it does have some negative effects on meat quality. Replacing 35% of corn grain in beef finishing diets with HPDDG does not affect moisture loss, and shear force of fresh beef products. However, inclusion of HPDDG in the diet at 35% of dietary DM produces small but unfavorable changes in sensory characteristics of cooked sausage. HPDDG produces unfavorable changes in the fatty acid profile, specifically an increase in linoleic acid, as well as an increase in polyunsaturated fatty acids. HPDDG included in beef finishing diets also increases lipid oxidation resulting in a decrease in shelf life.

IMPLICATIONS

With current high corn prices and increasing production costs in the feedlot industry, incorporating co-products into finishing diets at higher inclusion concentrations in place of more expensive ingredients may be attractive to provide economic advantages to feedlot producers. Co-product HPDDG may successfully replace up to 35% of corn grain in feedlot diets as other live performance and carcass variables were not affected. Because steer growth performance and carcass characteristics were not

compromised even though intake was lower with HPDDG, there is great potential to realize improved feed efficiency, decreased cost of gain, and improved carcass quality when using this co-product in finishing diets. Despite the lower fat concentrations in HPDDG detrimental effects were seen in meat quality. Due to the possibility of the fat not being biohydrogenated in the rumen there is increased amount of unsaturated fatty acids in the meat, resulting in decreased shelf life. HPDDG may not be the best supplementation in feedlot diets not only due to the detrimental effects in meat quality but also the limited availability.

ACKNOWLEDGEMENTS

We thank our supporting partners from the Agricultural Utilization Research Institute (AURI) and the Minnesota Corn Growers for funding this work. Additional thanks to Kip Karges from POET Nutrition for donating the co-products fed in this experiment. Thanks are expressed to personnel from the Meat Lab and Sensory Lab at the University of Minnesota for their assistance: P. Nelson and T. McNamara for meat processing, Z. Vickers and N. Bobowski for sensory analysis. Additional thanks to AURI for their assistance: R. Jorgenson for TBAR and fatty acid analysis. Final thanks to everyone involved in making this experiment a success.

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Table 1. Chemical and energy composition[a] (DM-basis) of conventional dried distillers grains plus solubles (DDGS) and high protein dried distillers grains (HPDDG).

	Corn Milling Co-Product[b]	
	DDGS	HPDDG
Dry Matter, %	91.0	91.3
Crude Protein, %	27.6	39.0
Acid Detergent Fiber, %	9.7	13.6
Neutral Detergent Fiber[c], %	23.9	23.6
Fat, %	10.9	5.1
Ca, %	0.07	0.04
P, %	0.96	0.54
S, %	0.84	0.69
Total Digestible Nutrients, %	82.2	76.7
NE_g, Mcal/cwt	63.5	59.7

[a]Analyzed by Dairyland Laboratories, Inc. (St. Cloud, MN). Values in table are the four samples analyzed monthly throughout the experiment. Monthly samples are average of composites of four samples, each taken at weekly intervals.

[b]Both corn milling co-products were sourced from POET Nutrition (Sioux Falls, SD). DDGS = dried distillers grains plus solubles; HPDDG = high protein dried distillers grains containing no solubles.

Table 2. Formulated ingredient and analyzed chemical and energy composition[1] of experimental diets.

	Experimental Diet[2]					
Ingredient	CON		DDGS		HPDDG	
Dry-Rolled Corn, %	82.5		51.0		51.0	
Alfalfa Haylage, %	12.0		12.0		12.0	
Conventional DGS[3], %	0.0		35.0		0.0	
HPDG[4], %	0.0		0.0		35.0	
Supplement, %	5.5[5]		2.0[6]		2.0[6]	
Chemical	Mean	SD	Mean	SD	Mean	SD
DM, %	75.2	0.8	75.7	2.2	75.7	1.9
CP, %	12.1	0.4	17.1	0.5	22.0	0.1
Fat, %	3.55	0.26	5.96	0.29	3.53	0.09
ADF, %	9.0	1.5	10.6	0.7	9.7	1.0
aNDF[7], %	15.6	2.5	22.4	0.7	20.7	1.7
Starch, %	55.0	4.3	33.9	0.7	36.0	2.3
Ca, %	0.70	0.1	0.97	0.1	1.03	0.06
P, %	0.31	0.01	0.53	0.01	0.34	0.01
S, %	0.15	0.02	0.42	0.01	0.37	0.01
Energy	Mean	SD	Mean	SD	Mean	SD
TDN, %	79.9	1.8	77.2	1.3	75.7	1.0
NE_g[8], Mcal/kg (OARDC)	1.29	0.05	1.29	0.04	1.26	0.02
NE_g[9], Mcal/kg (NRC)	1.45	---	1.47	---	1.48	---

[1]Analyzed by Dairyland Laboratories, Inc. (St. Cloud, MN). Mean values in table are the average of four diet samples analyzed monthly throughout the experiment. Monthly samples are composites of four diet samples, each collected at weekly intervals. Standard deviation (SD) of nutrient analyses are presented following their respective mean values. All values are reported on a DM-basis.

[2]Experimental diets included: CON, containing 0% corn-milling co-products; DDGS, containing 35% conventional dried distillers grains plus solubles; and HPDDG, containing 35% high protein dried distillers grains.

[3]Conventional dried distillers grains plus solubles sourced from POET Nutrition, Lake Crystal, MN.

[4]High protein dried distillers grains sourced from POET Nutrition, Glenville, MN.

[5]Supplement contained 60% CP and 0.55 g monensin sodium per kg DM (DM-basis).

[6]Supplement contained 1.65 g monensin sodium per kg DM (DM-basis).

[7]NDF was analyzed using sodium sulfite.

[8]Analyzed by Dairyland Laboratories using OARDC equations based on ADF and digestibility estimates.

[9]Calculated using NRC (1996) equations based on observed steer intake and weight gain.

Table 3. Effect of feeding 35% high protein dried distillers grains in place of DRC on feedlot steer performance.

	Treatment Diet[1]				
	CONTROL	DDGS	HPDDG	SEM[2]	*P*-Value[3]
Initial BW, lb	319	318	314	18	0.90
Carc. Adj. Final Live BW, kg	553	552	540	20	0.54
Carc. Adj. Overall BW gain, kg	234	235	226	12	0.49
DMI, overall, kg/d	10.3	10.2	9.8	0.4	0.08
DMI, d 28-end of finishing, kg/d	10.8	10.4	9.9	0.4	0.008
Carc. Adj. Overall ADG, kg	2.00	2.00	1.91	0.11	0.49
ADG, d 28-end of finishing, lb	2.20	2.13	2.09	0.13	0.44
Carc. Adj. Feed:Gain	5.267	5.130	5.107	0.119	0.59
Feed:Gain, d 28-end of finishing	4.993	4.946	4.806	0.136	0.60

[1]Treatment diets included: Control, containing 0% corn-milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and LFDG, containing 35% low fat dried distillers grains.

[2]Highest standard error of the mean reported.

[3]Significance declared with P-values ≤ 0.05; Trends discussed with $0.05 < P$-values ≤ 0.10.

Table 4. Least square means and main contrasts for carcass characteristics from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* -Values)	
	CON	DDGS	HPDDG	SEM[1]	*P*-Value	CON vs. DDG[2]	DDGS vs. HPDDG
Hot Carcass Weight, kg	337	336	328	12	0.54	0.53	0.36
Cold Carcass Weight, kg	334	334	326	12	0.54	0.56	0.34
Carcass Shrink, %	0.76	0.62	0.70	0.06	0.24	0.17	0.32
Dressing Percentage, %	59.6	59.8	59.9	0.4	0.22	0.64	0.78
USDA Yield Grade	2.56	2.75	2.69	0.12	0.54	0.29	0.71
YG 2, %	44.0	25.0	31.0	0.1	0.51	0.28	0.70
YG 3, %	56.0	75.0	69.0	0.1	0.51	0.28	0.70
USDA Quality Grade[3]	1.19	1.13	1.31	0.12	0.51	0.83	0.26
Prime, %	0.0	0.0	6.0	0.03	0.35	0.47	0.21
Choice, %	81.0	88.0	75.0	0.1	0.66	1.00	0.36
Select, %	19.0	13.0	19.0	0.1	0.86	0.78	0.63
Marbling Score[4]	561	594	609	21	0.26	0.12	0.62
Ribeye Area, cm^2	77.93	78.39	76.84	0.20	0.57	0.52	0.40
Backfat, cm	1.42	1.57	1.65	0.03	0.18	0.08	0.51
Kidney, Pelvic, Heart fat, %	2.4	2.7	2.6	0.2	0.35	0.16	0.70

[1]Standard error=weighted standard error equation: Σ(error*df)/Σ(total df).

[2]CON vs. distillers grains-containing treatments

[3]1=choice, 2= select, and 3=prime

[4]500=small, 600=modest

Table 5. Least square means and main contrasts for moisture and fabrication loss from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

		Treatment					Main Contrasts (*P* -Values)	
	n	CON	DDGS	HPDDG	SEM[1]	*P*-Value	CON vs DDG[2]	DDGS vs. HPDDG
Drip Loss, %	42	0.75	0.43	0.62	0.19	0.49	0.34	0.49
Purge Loss, %	43	1.83	1.85	2.22	0.15	0.16	0.53	0.07
Fabrication Loss, Inside Round[3], %	40	1.22	1.20	1.25	0.02	0.20	0.91	0.08
Fabrication Loss, Strip Loin[4], %	43	0.71	0.68	0.69	0.01	0.36	0.17	0.78
Fabrication Loss, Shoulder Clod[5], %	44	1.28	1.26	1.30	0.02	0.20	0.88	0.08

[1]Standard error=weighted standard error equation: Σ(error*df)/Σ(total df).
[2]CON vs. distillers grains-containing treatments
[3]IMPS #169
[4]IMPS#180
[5]IMPS#114

Table 6. Pooled least square means and main contrast for sensory analysis and shear force values of steaks and summer sausage from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* -Values)	
Steaks (n = 108)	CON	HPDDG	DDGS	SEM[1]	*P* - value	Con vs. DGS[2]	DDGS vs. HPDDG
Overall Liking[3]	71.5	68.6	70.5	1.45	0.10	0.11	0.16
Flavor Liking[3]	71.3	68.1	70.3	1.48	0.06	0.08	0.12
Texture Liking[3]	68.8	68.3	70.5	1.61	0.47	0.69	0.25
Toughness[4]	7.27	7.17	6.62	0.32	0.17	0.25	0.14
Juciness[4]	7.72	8.49	7.81	0.36	0.10	0.21	0.09
Off -Flavor[4]	4.30	4.68	4.30	0.36	0.20	0.38	0.12
WBSF, kg	2.54	2.37	2.88	0.22	0.25	0.72	0.10
Summer Sausage (n = 101)							
Overall Liking	70.0[a]	68.1[ab]	66.28[b]	1.35	0.01	0.01	0.13
Flavor Liking	70.6[a]	69.1[ab]	67.40[b]	1.32	0.04	0.04	0.20
Texture Liking	64.8[a]	64.1[a]	61.00[b]	1.50	0.01	0.05	0.02
Toughness	5.74[a]	6.19[b]	5.23[c]	0.36	< 0.001	0.89	< 0.001
Sourness[4]	5.22	5.00	4.77	0.33	0.15	0.10	0.32
Off –Flavor	4.41	4.85	4.81	0.37	0.16	0.05	0.91

[abc]Means in the same row having different superscript differ ($P < 0.05$)

[1]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df).

[2]Con vs. distillers grains-containing treatments

[3]Overall liking, flavor liking, and texture liking were measured on a labeled affective magnitude scale with psychologically placed markers: 0 = strongest dislike imaginable, 120 = strongest like imaginable

[4]Toughness, sourness, juiciness, and were measured on a line scale with placed markers: 0 = none, 20 = extremely intense

Table 7. Least square means and main contrasts for objective[1] and subjective[2] color values for strip steaks (*longissimus lumborum*), from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* -Values)	
	CON	DDGS	HPDDG	*P*-Value	SEM[3]	Con vs. DG[4]	DDGS vs. HPDDG
L*	37.09	37.31	37.16	0.87	0.30	0.69	0.73
a*	7.45[a]	6.56[b]	6.03[b]	< 0.001	0.21	< 0.001	0.08
b*	11.73	11.58	11.40	0.43	0.18	0.27	0.49
Lean Color	5.85[a]	5.24[b]	4.83[c]	< 0.001	0.12	< 0.001	0.02
Overall Appearance	5.74[a]	5.17[b]	4.77[c]	< 0.001	0.11	< 0.001	0.02
Surface Discoloration	8.67[a]	7.53[b]	6.84[c]	< 0.001	0.22	< 0.001	0.03

[1]L* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness (positive values = yellow, negative values=blue).

[2]Lean color (1 = extremely brown, 8 = extremely bright, cherry red); overall appearance (1 = extremely undesirable, 8 = extremely desirable); surface discoloration (1 = 91-100% discoloration, 11 = 0% discoloration)

[3]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df).

[4]CON vs. distillers containing treatments.

[abc]Means in the same row having different superscript differ ($P < 0.05$)

Table 8. Least square means and main contrasts for objective[1] and subjective[2] color values for fresh ground beef, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* -Values)	
	CON	DDGS	HPDDG	*P* - Value	SEM[3]	CON vs. DG[4]	DDGS vs. HPDDG
L*	44.34	45.33	45.69	0.15	0.51	0.06	0.63
a*	6.69	6.63	6.13	0.16	0.22	0.25	0.13
b*	14.53	14.46	14.83	0.23	0.16	0.53	0.11
Lean Color	3.46[a]	3.17[b]	2.96[b]	0.001	0.09	< 0.001	0.11
Overall Appearance	3.52[a]	3.22[b]	3.06[b]	< 0.001	0.08	< 0.001	0.18
Surface Discoloration	4.31[a]	3.90[ab]	3.53[b]	0.001	0.15	0.001	0.08

[1]L* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness (positive values = yellow, negative values = blue).

[2]Lean color (1= extremely brown, 8=extremely bright, cherry red); overall appearance (1 = extremely undesirable, 8 = extremely desirable); surface discoloration (1= 91-100% discoloration, 11= 0% discoloration)

[3]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df).

[4]CON vs. distillers containing treatments.

[abc]Means in the same row having different superscript are differ ($P < 0.05$).

Table 9. Least square means and main contrasts for objective[1] subjective[2] color values for bologna, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* - Values)	
	CON	DDGS	HPDDG	*P* -Value	SEM[3]	CON vs. DGS[4]	DDGS vs. HPDDG
L*	51.74	51.62	51.63	0.51	0.08	0.25	0.95
a*	7.64	7.52	7.54	0.55	0.08	0.30	0.85
b*	11.84	11.85	11.86	0.96	0.04	0.87	0.84
Surface Discoloration	6.38[a]	5.12[b]	5.53[ab]	0.10	0.38	0.05	0.47
Overall Appearance	3.67[a]	3.30[b]	3.40[b]	0.03	0.31	0.03	0.53
Lean Color	4.45[a]	3.85[b]	4.01[ab]	0.07	0.35	0.03	0.50

[1]L* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness (positive values = yellow, negative values = blue).

[2]Lean color (1 = extremely brown, 8 = extremely bright, cherry red); overall appearance (1 = extremely undesirable, 8 = extremely desirable); surface discoloration (1 = 91-100% discoloration, 11 = 0% discoloration)

[3]Standard error=weighted standard error equation: Σ(error*df)/Σ(total df).

[4]CON vs. distillers containing treatments.

[abc]Means in the same row having different superscript differ ($P < 0.05$)

Table 10. Least square means and main contrasts for objective[1] subjective[2] color values for summer sausage, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles,

and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* -Values)	
	CON	DDGS	HPDDG	*P*-Value	SEM[3]	CON vs. DGS[4]	DDGS vs. HPDDG
L*	49.33	50.47	50.35	0.23	0.50	0.09	0.87
a*	9.90	10.25	9.95	0.28	0.16	0.32	0.21
b*	10.49	10.70	10.78	0.57	0.19	0.32	0.77
Lean Color	4.92	5.01	4.95	0.44	0.05	0.23	0.71
Surface Discoloration	10.30	10.01	10.03	0.16	0.01	0.23	0.13
Overall Appearance	4.86	4.86	4.84	0.82	0.03	0.82	0.57

[1]SL* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness (positive values = yellow, negative values = blue)

[2]Lean color (1=extremely brown, 8 = extremely bright, cherry red); overall appearance (1 = extremely undesirable, 8 = extremely desirable); surface discoloration (1 = 91-100% discoloration, 11 = 0% discoloration)

[3]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df)

[4]CON vs. distillers containing treatments.

Table 11. Least square means and main contrasts for total fatty acids concentrations from 12th rib back fat of strip loins from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* - Values)	
	CON	DDGS	HPDDG	SEM[3]	*P* - Value	Con vs. DGS[4]	DDGS vs. HPDDG
Fatty Acids[1,2]							
12:0 Lauric	0.06[a]	0.06[a]	0.08[b]	0.00	< 0.001	0.008	< 0.001
14:0 Myristic	3.37[ab]	3.15[a]	3.59[b]	0.09	0.009	0.972	0.00
15:0 Pentadecanoic	0.38[a]	0.32[b]	0.44[c]	0.01	< 0.001	0.652	< 0.001
16:0 Palmitic	26.54[a]	24.80[b]	27.18[a]	0.24	< 0.001	0.067	< 0.001
17:0 Margaric	1.18[a]	0.91[b]	1.24[a]	0.04	< 0.001	0.025	< 0.001
18:0 Steric	13.49[a]	15.77[b]	13.77[a]	0.55	0.01	0.067	0.02
14:1 Myristoleic	0.99[a]	0.81[b]	0.85[b]	0.04	0.01	0.003	0.50
14:1t Myristoleic Acid	0.12	0.12	0.13	0.00	0.43	0.457	0.29
16:1 Palmitoleic	4.01[a]	3.35[b]	3.67[ab]	0.15	0.01	0.009	0.14
16:1t Palmitoleic Acid	0.26	0.25	0.24	0.01	0.18	0.109	0.35
17:1 Heptadecenoic	0.79[a]	0.52[b]	0.70[c]	0.02	< 0.001	<0.001	< 0.001
18:1 (ω-9) Oleic	41.73	43.34	41.46	1.87	0.75	0.771	0.48
20:1 (ω-9) Eicosenoic	0.57	0.59	0.59	0.02	0.77	0.470	1.00
18:2 (ω-6) Linoleic	1.51[a]	3.86[b]	4.21[b]	0.16	< 0.001	<0.001	0.13
18:3 (ω-3) Linolenic	0.33[a]	0.26[b]	0.25[b]	0.02	0.04	0.013	0.78
Total Fatty Acids	95.47	98.56	98.82	1.71	0.32	0.135	0.96

[abc]Means in the same row having different superscript differ ($P < 0.05$)

[1]Fatty acids are represented as number of carbon atoms:number of carbon-carbon double bonds

[2]ω = omega

[3]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df).

[4]CON vs. distillers containing treatments.

Table 11 Continued. Least square means and main contrasts for total fatty acids concentrations from 12th rib back fat of strip loins from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains

	Treatment					Main Contrasts (*P* - Values)	
	CON	DDGS	HPDDG	SEM[3]	*P* - Value	Con vs. DGS[4]	DDGS vs. HPDDG
Fatty Acids[1,2]							
SFA[5]	43.46	43.78	44.61	0.65	0.44	0.36	0.37
UFA[6]	49.13	52.20	51.03	1.93	0.53	0.30	0.67
MUFA[7]	47.30	48.09	46.57	1.95	0.86	0.10	0.59
PUFA[8]	1.84[a]	4.12[b]	4.46[b]	0.15	< 0.001	< 0.001	0.11
MUFA:SFA Ratio[9]	1.10	1.10	1.05	0.05	0.70	0.73	0.45
PUFA:SFA Ratio[10]	0.04[a]	0.09[b]	0.10[b]	0.00	< 0.001	< 0.001	0.17
(ω-6) PUFA[11]	1.51[a]	3.86[b]	4.21[b]	0.16	< 0.001	< 0.001	0.13
(ω-3) PUFA[12]	0.33[a]	0.26[b]	0.25[b]	0.02	0.04	0.01	0.78
(ω-6):(ω-3)[13]	4.80[a]	16.67[b]	17.14[b]	1.37	< 0.001	< 0.001	0.81
Iodine Value[14]	46.20[a]	48.28[b]	47.56[a]	0.50	0.02	0.01	0.31

[1]Fatty acids are represented as number of carbon atoms: number of carbon-carbon double bonds

[2]ω = omega

[3]Standard error = weighted standard error equation: Σ(error*df)/Σ(total df).

[4] CON vs. distillers containing treatments.

[5]Saturated fatty acids = calculated sum of fatty acids presented in the study that contain no double bonds

[6]Unsaturated fatty acids = calculated sum of fatty acids presented in the study that contain double bonds

[7]Monounsaturated fatty acids = calculated sum of fatty acids presented in the study that contain on double bond

[8]Polyunsaturated fatty acids = calculated sum of fatty acids presented in the study that contain two or more double bonds

[9]Calculated ratio of monounsaturated fatty acids (MUFA) to saturated fatty acids (SFA)

[10]Calculated ratio of polyunsaturated (PUFA) to saturated fatty acids (SFA)

[11]Omega-6 = calculated sum of all omega-6 fatty acids presented in the study

[12]Omega-3 = calculated sum of all omega-3 fatty acids presented in the study

Table 12. Fatty acid profile of conventional dried distillers grains plus solubles (DDGS) and high protein dried distillers grains (HPDDG) used in the present experiment.

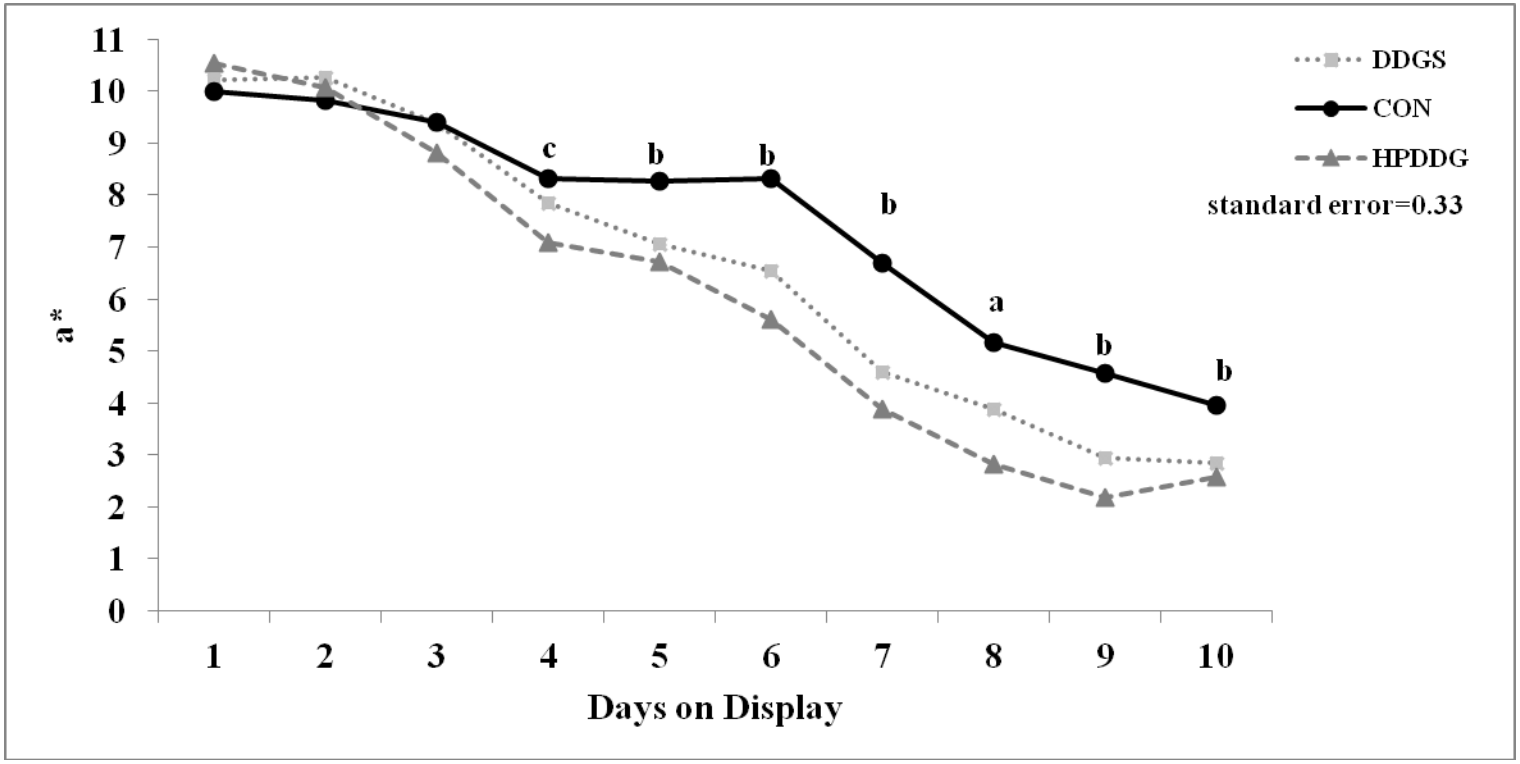
	Corn Milling Co-Product[2]	
	HPDDG	DDGS
6:0 Caproic	0.003	-
8:0 Caprylic	0.008	0.002
12:0 Lauric	0.033	0.016
14:0 Mystric	0.077	0.072
15:0 Pentadecanoic	0.018	0.012
16:0 Palmitic	17.084	15.216
16:1 Palmitoleic	0.170	0.112
17:0 Margaric	0.084	0.077
18:0 Steric	2.391	2.144
18:1 Oleic	25.233	27.101
18:2 Linoleic	51.795	52.692
18:3 Linolenic	1.637	1.241
20:0 Arachidic	0.476	0.454
20:1 Gadoleic	0.310	0.305
20:2 Eicosadienoic	0.067	0.042
20:4 Arachiodonic	0.062	0.040
21:0 Heneicosanoic	0.023	0.016
22:0 Behenic	0.209	0.182
22:1 Erucic	0.008	0.012
22:2 Docosadienoic	0.004	-
22:3 Docosatrienoic	0.016	0.011
24:0 Lignoceric	0.287	0.248
24:1 Nervonic	0.002	0.005
SFA	20.69	18.44
MFA	25.72	27.54
PUFA	53.58	54.03

[a]Analyzed by Minnesota Valley Laboratory Testing, Inc. (New Ulm, MN). Values in table are the average of the composites of ten samples throughout the experiment

[b]Both corn milling co-products were sourced from POET Nutrition (Sioux Falls, SD).

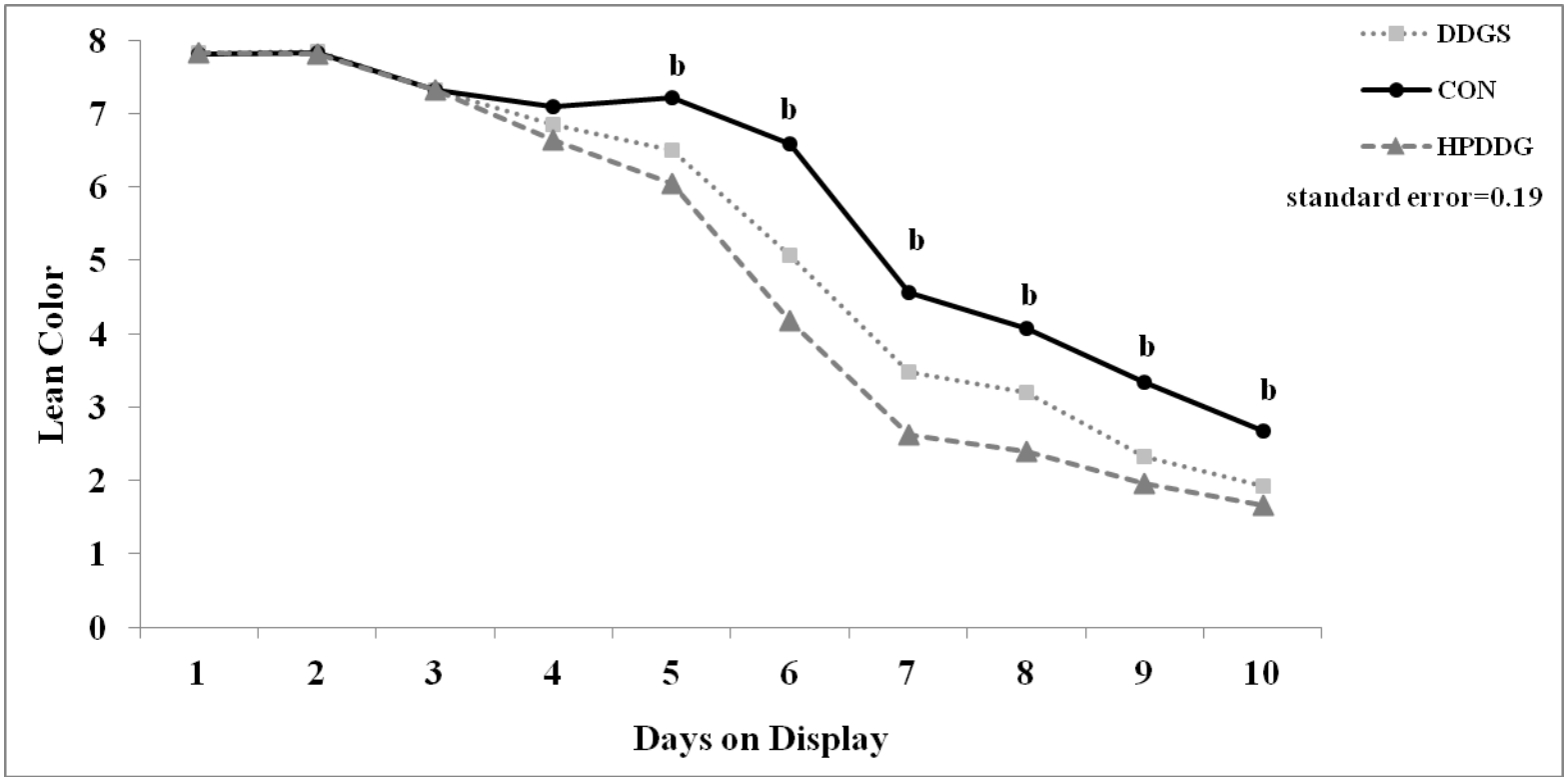
DDGS = "raw starch" dried distillers grains plus solubles; HPDDG = high protein dried distillers grains

Figure 1. Objective redness values (a*) of strip steaks (*longissimus lumborum*), from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



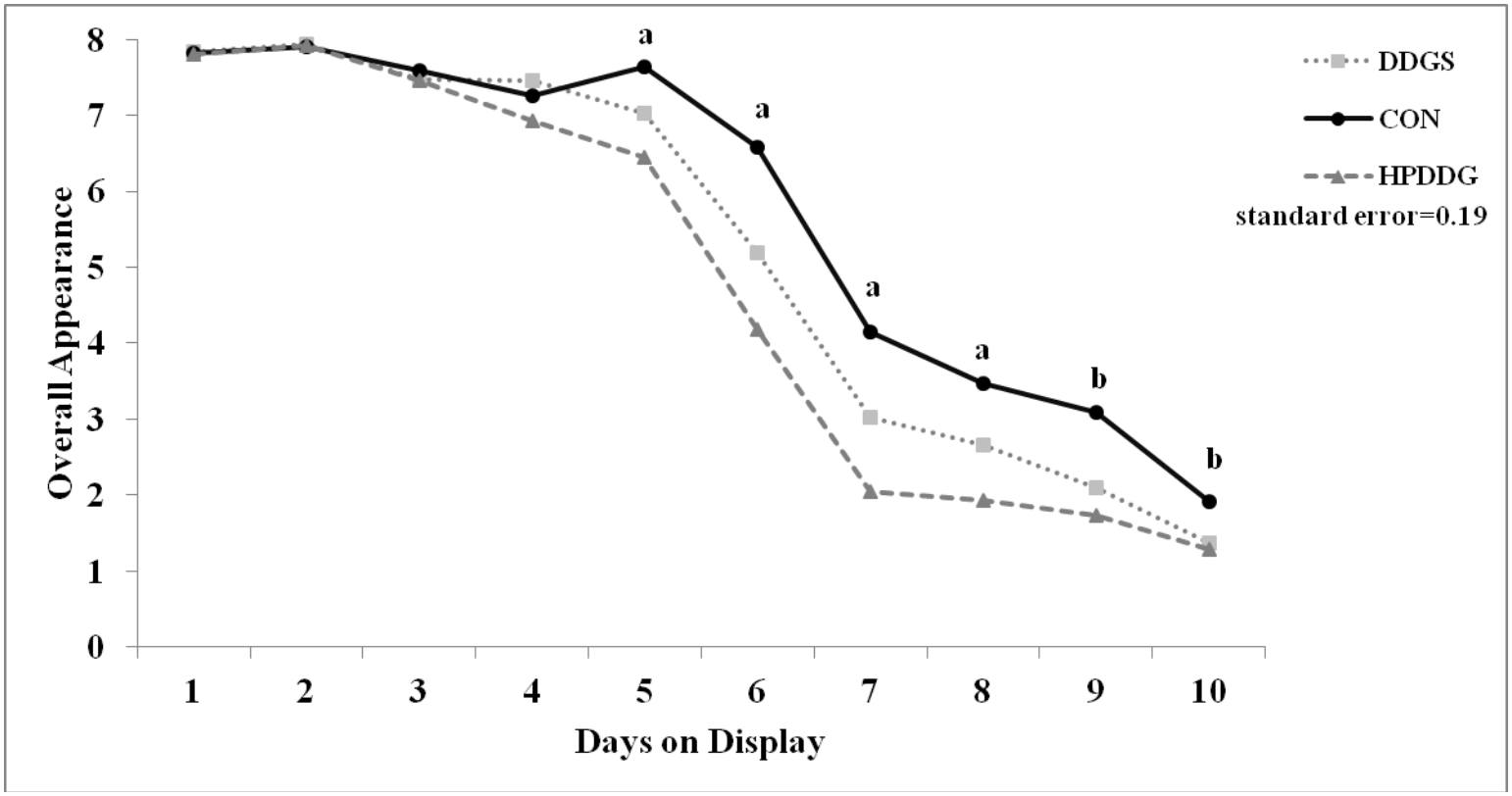
[a]Significant ($P < 0.05$) difference between all treatments
[b]Significant ($P < 0.05$) difference between DG and CON
[c]CON and HPDDG are significantly ($P < 0.05$) different while DDGS is different from neither treatment

Figure 2. Subjective lean color values of strip steaks (*longissimus lumborum*), from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



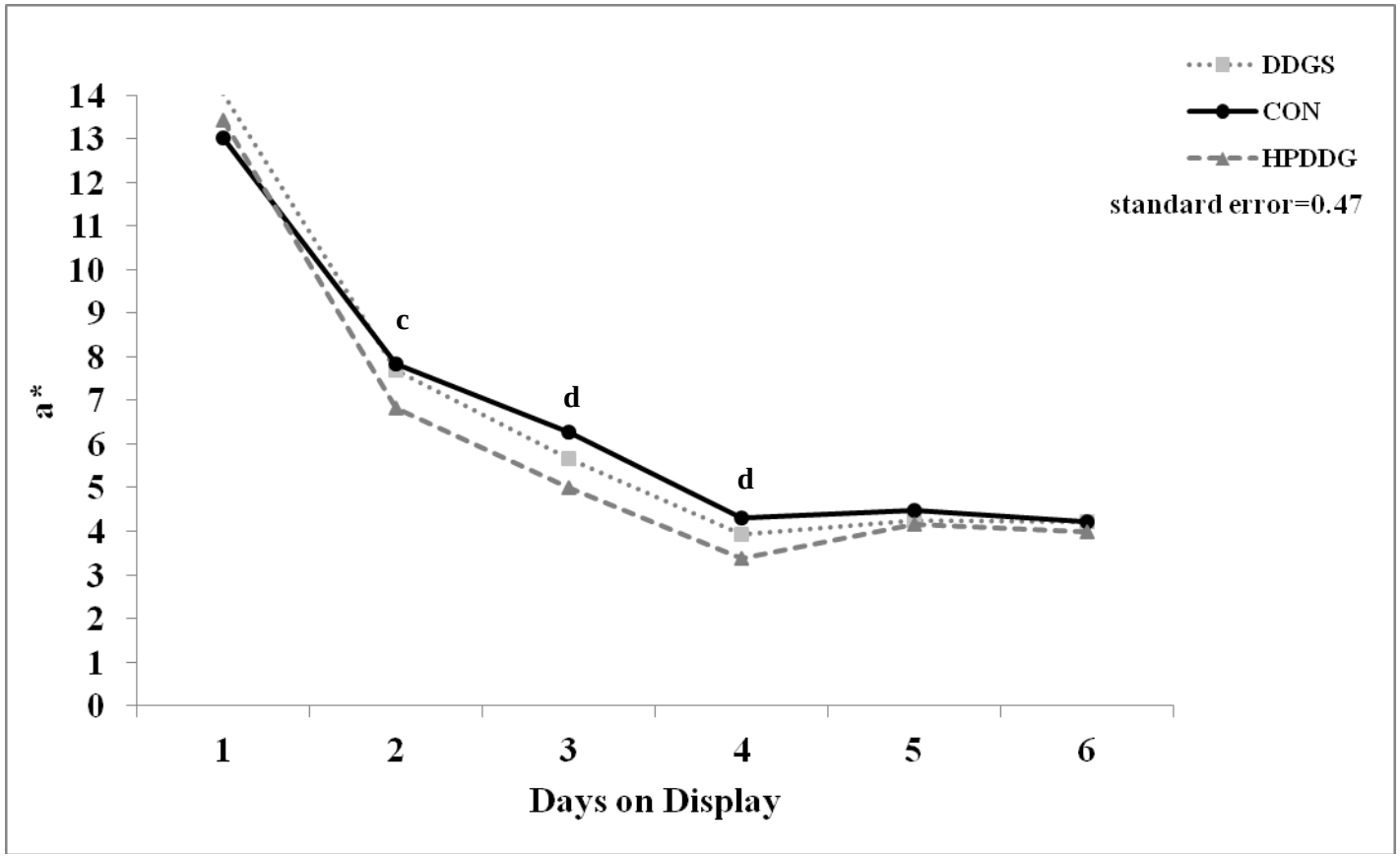
[b]Significant ($P < 0.05$) difference between DG and CON

Figure 3. Subjective overall appearance color values of strip steaks (*longissimus lumborum*), from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



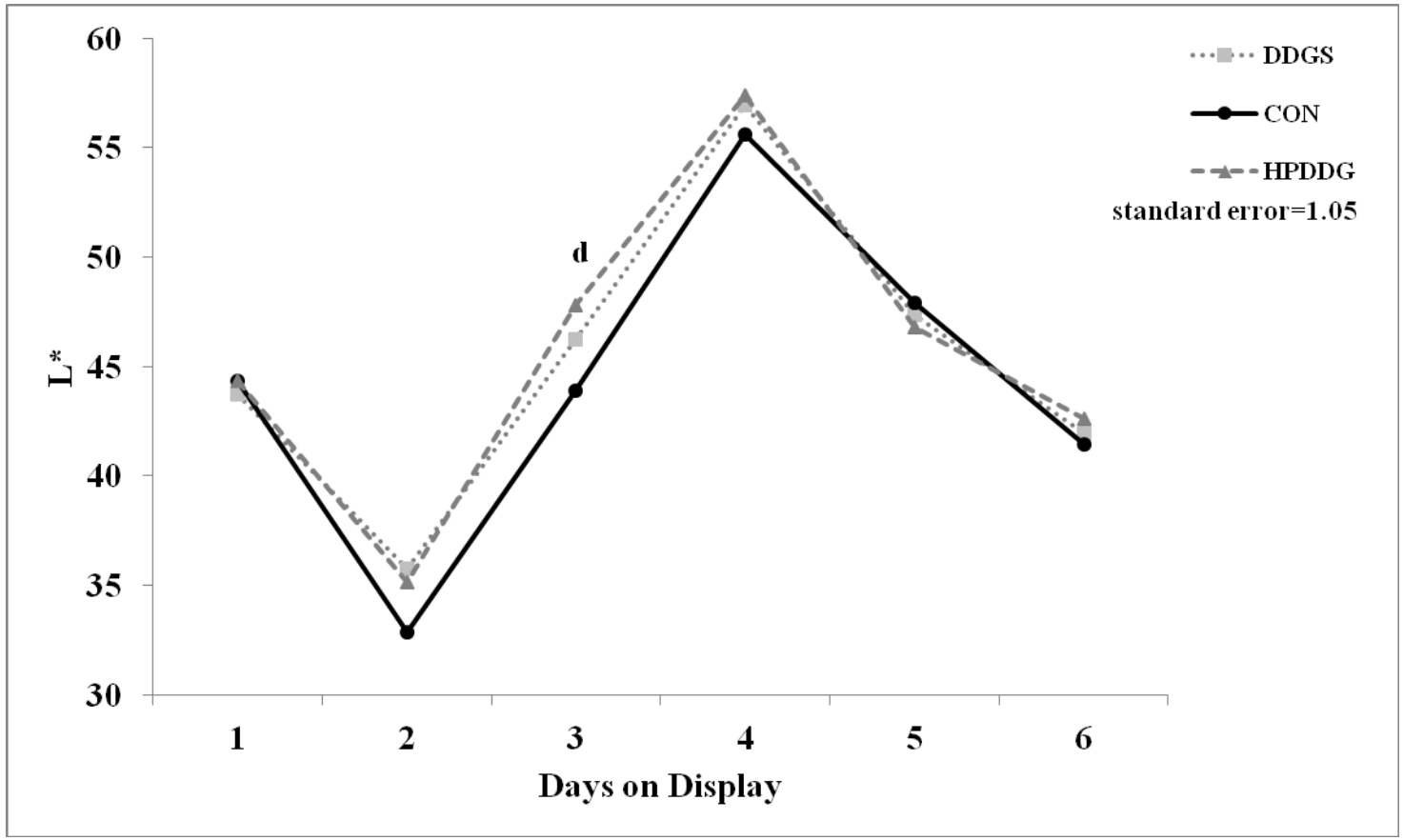
[a]Significant ($P < 0.05$) difference between all treatments
[b]Significant ($P < 0.05$) difference between DG and CON

Figure 4. Objective redness values (a*) of ground beef, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



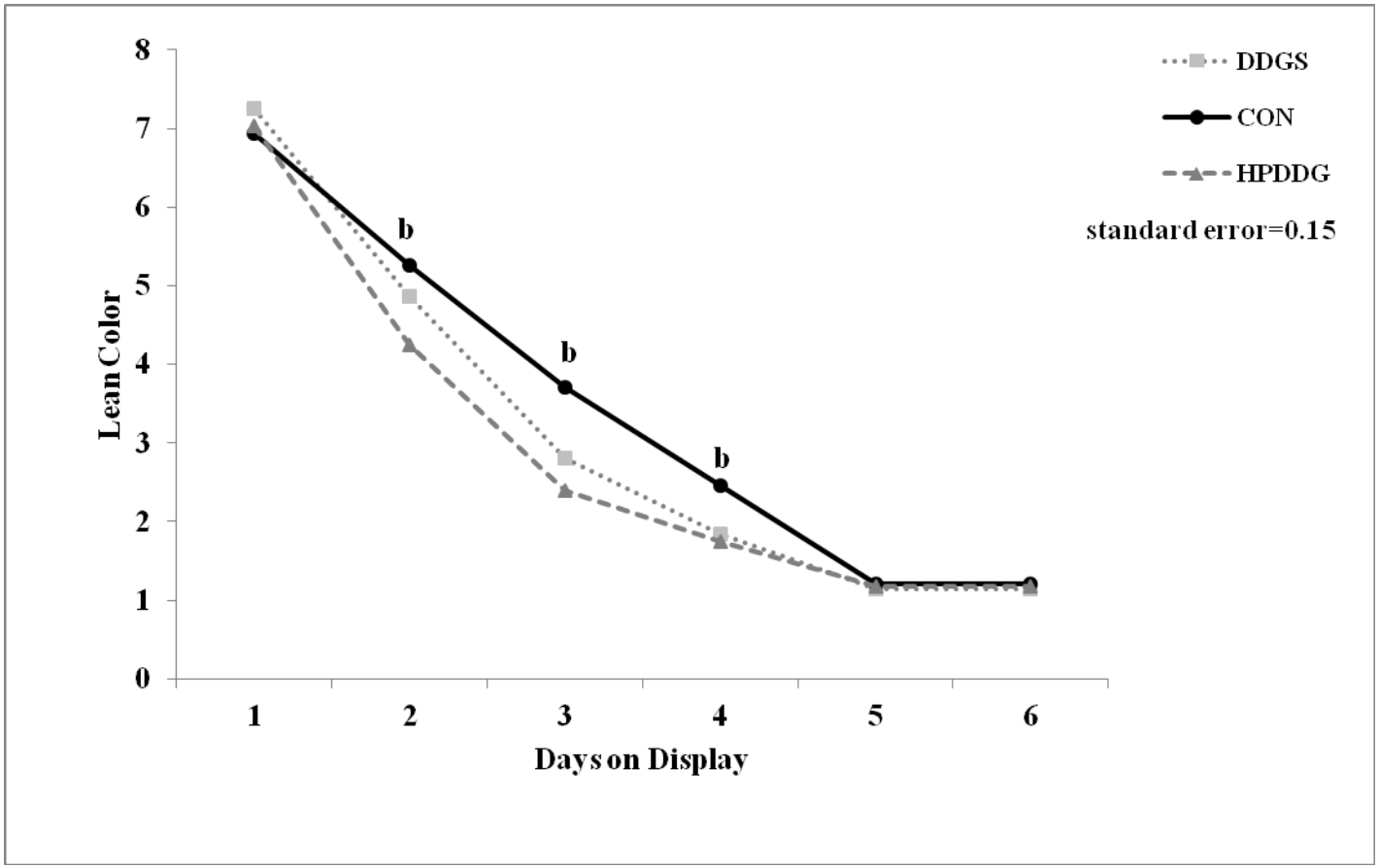
[c]CON and DDGS are significantly ($P < 0.05$) different while HPDDG is different from neither treatment
[d]CON and HPDDG are significantly ($P < 0.05$) different while DDGS is different from neither treatment

Figure 5. Objective lightness values (L*) of ground beef, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



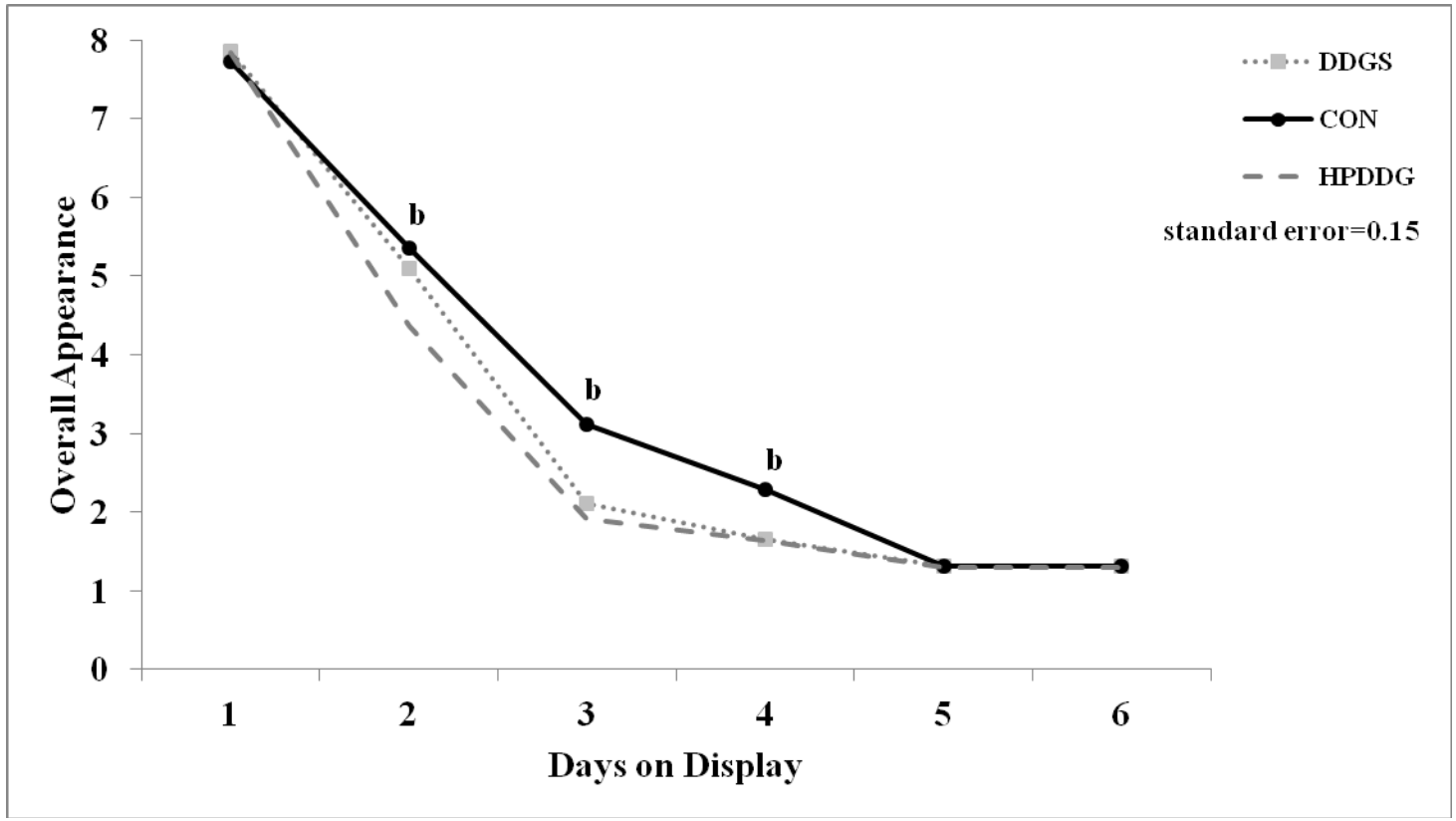
[d]CON and HPDDG are significantly ($P < 0.05$) different while DDGS is different from neither treatment

Figure 6. Subjective lean color values of ground beef, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



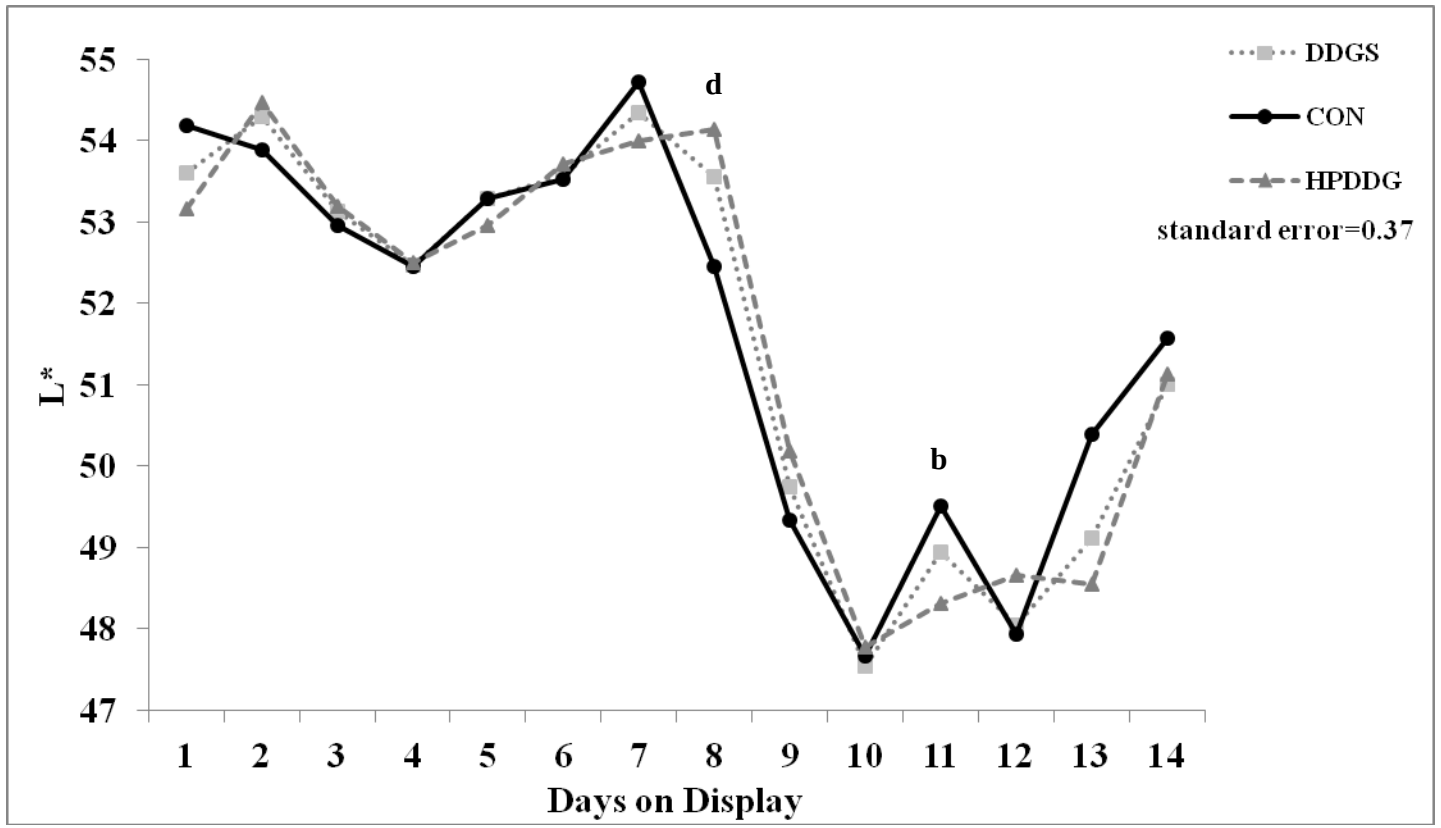
[b]Significant ($P < 0.05$) difference between DG and CON

Figure 7. Subjective overall appearance color values of ground beef, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[b]Significant ($P < 0.05$) difference between DG and CON

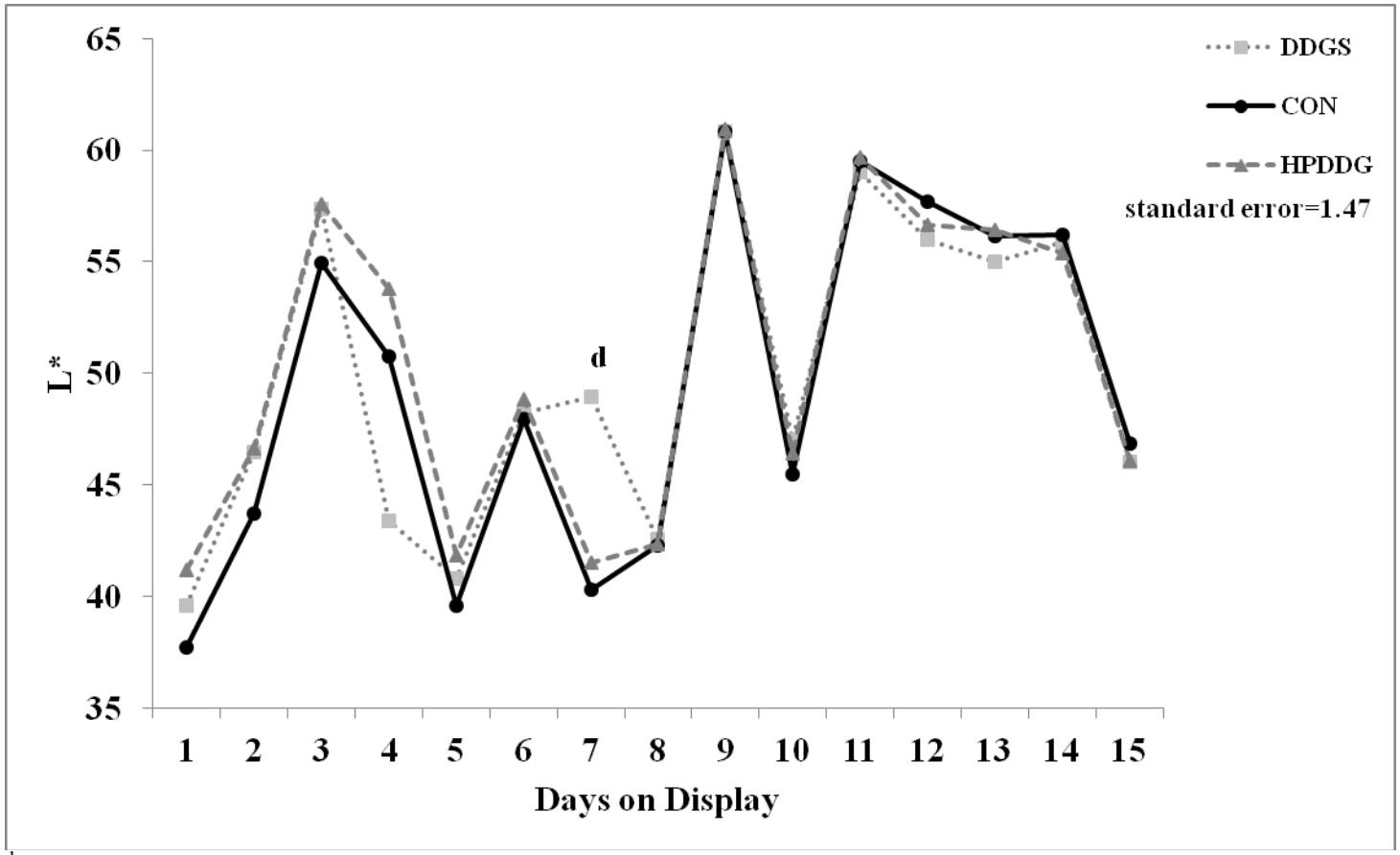
Figure 8. Objective lightness values (L*) of bologna, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[b]Significant ($P < 0.05$) difference between DG and CON

[d]CON and HPDDG are significantly ($P < 0.05$) different while DDGS is different from neither treatment

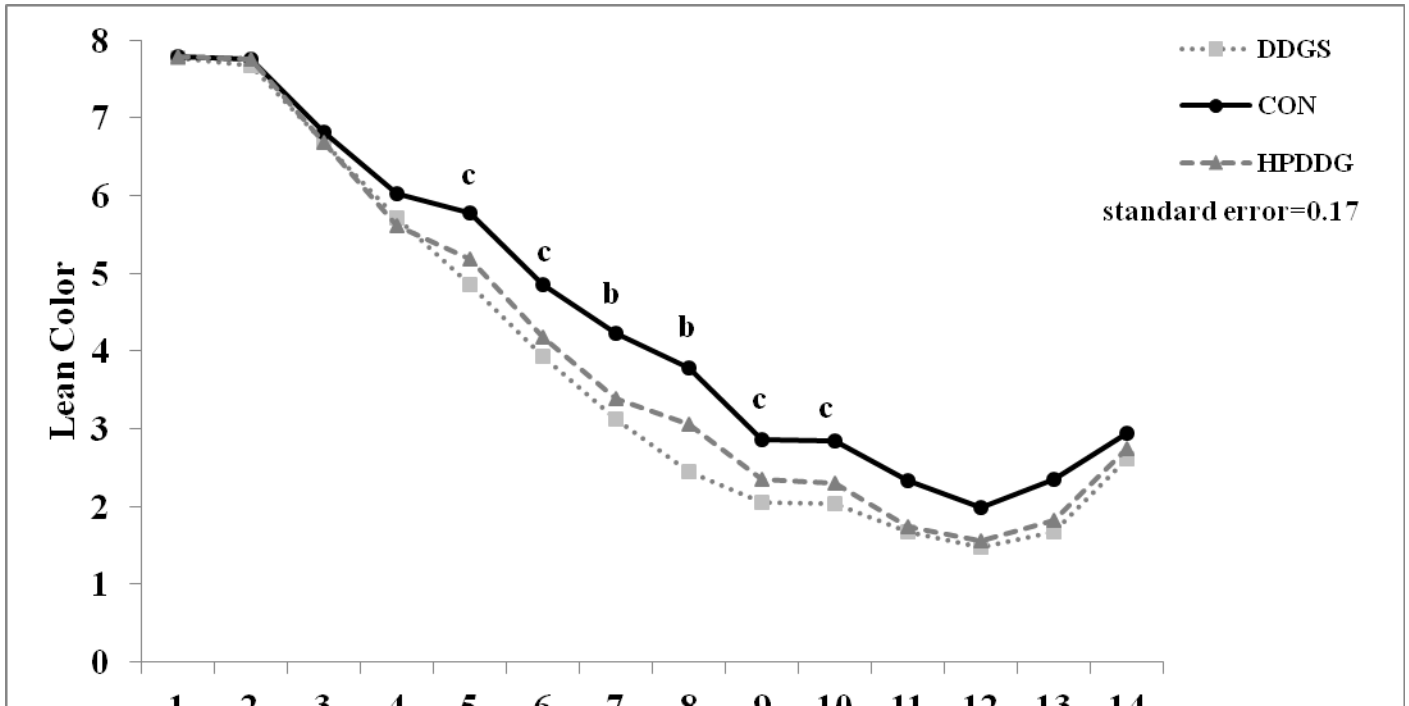
Figure 9. Objective lightness values (L*) of summer sausage, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS , containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[d] CON and HPDDG are significantly (P<0.05) different well DDGS is different from neither treatment

[d]CON and HPDDG are significantly ($P < 0.05$) different while DDGS is different from neither treatment

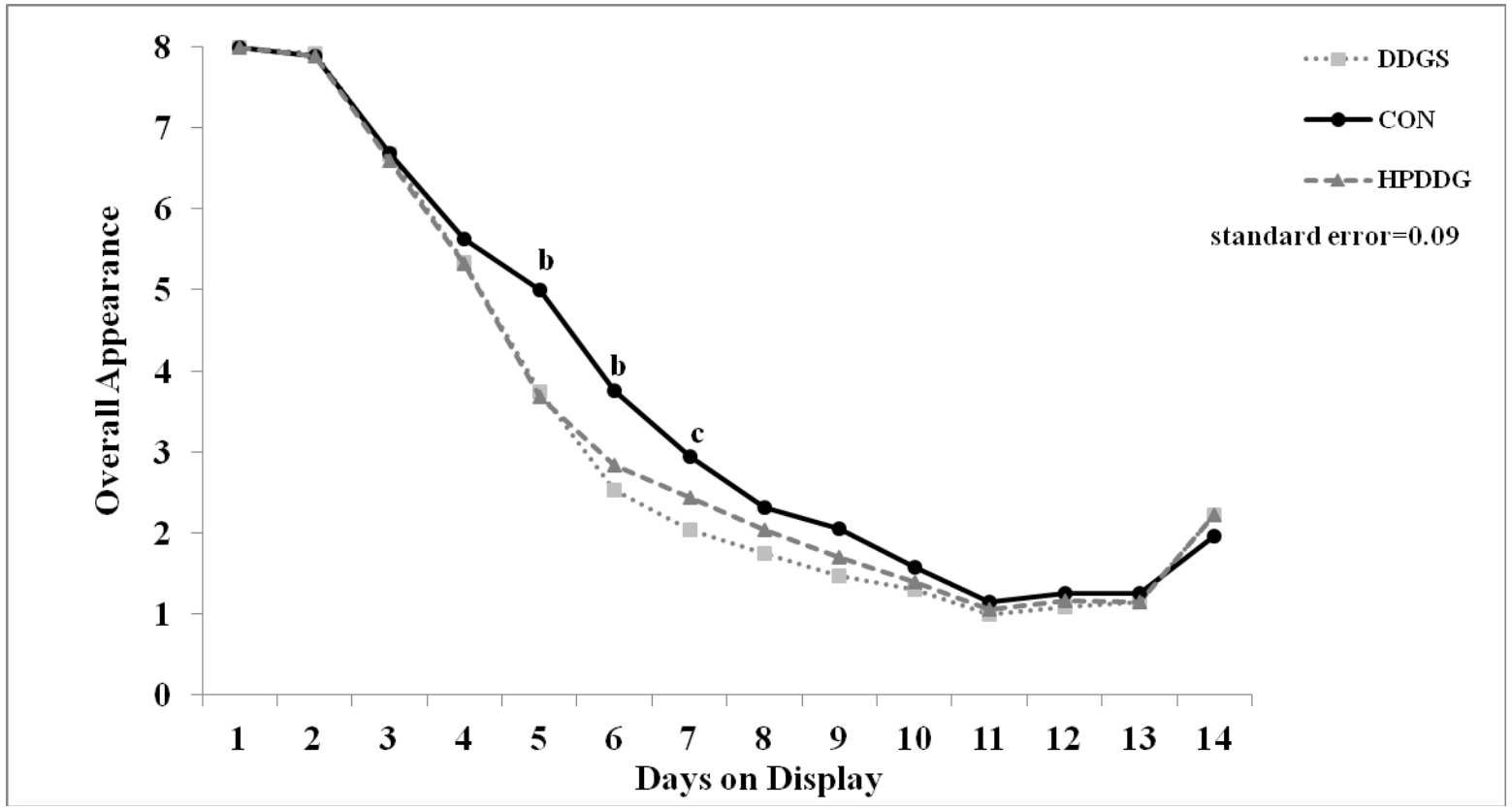
Figure 10. Subjective surface lean color values of bologna, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[b] Significant ($P < 0.05$) difference between DG and CON

[c]CON and DDGS are significantly ($P < 0.05$) different while HPDDG is different from neither treatment

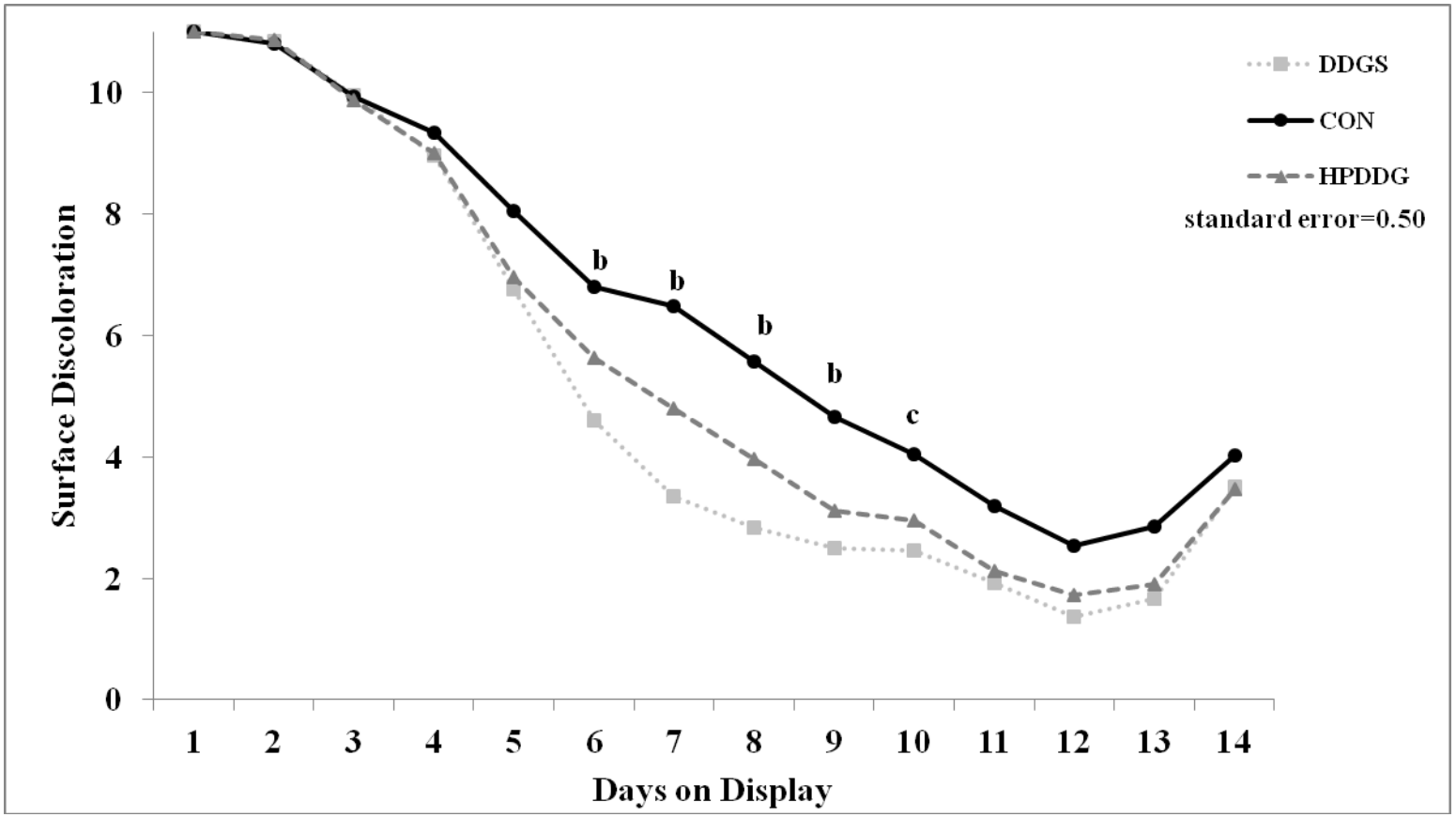
Figure 11. Subjective surface overall appearance values of bologna, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[b]Significant ($P < 0.05$) difference between DG and CON

[c]CON and DDGS are significantly ($P < 0.05$) different while HPDDG is different from neither treatment

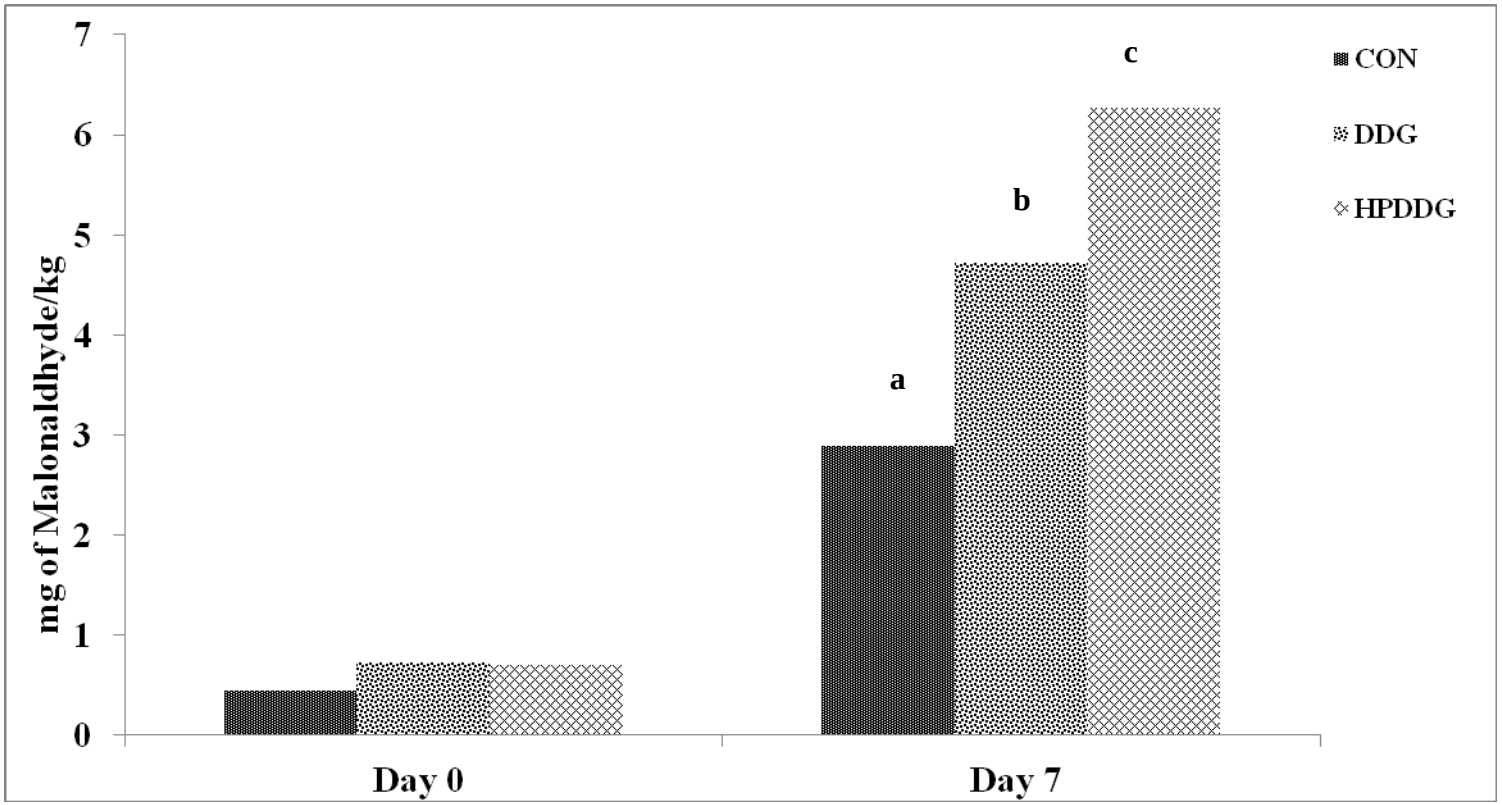
Figure 12. Subjective surface discoloration values of bologna, from steers fed a control diet (CON) containing 0% corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[b]Significant ($P < 0.05$) difference between DG and CON

[c]CON and DDGS are significantly ($P < 0.05$) different while HPDDG is different from neither treatment

Figure 13. Thiobarbituric acid reactive substances [TBARS (mg of malonaldhyde/kg) of BF] measured pre and post-retail color display in steaks from steers fed a control, (CON) containing 0% diet corn milling co-products, DDGS, containing 35% conventional dried distillers grains plus solubles, and HPDDG, containing 35% high protein dried distillers grains



[abc]Means in the same row having different superscript differ ($P < 0.05$)