Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers grains with solubles\textsuperscript{1,2}

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ABSTRACT: The objective of this study was to evaluate the influence of dietary protein and fat from distillers dried grains with solubles (DDGS) on feedlot performance, carcass characteristics, and meat quality in finishing steers. Angus-cross steers (n = 105; 443 ± 20 kg of BW) were blocked by BW and randomly assigned to 1 of 5 dietary treatments: 1) corn-based diet with DDGS included at 25% of DM (CON), 2) CON with DDGS included at twice the amount of CON (50% of DM; 50DDGS), 3) CON with added corn protein to equal the CP in the 50DDGS diet (CON+CP), 4) CON with added vegetable oil to equal the fat in the 50DDGS diet (CON+VO), and 5) CON with protein and fat added to equal the CP and fat in the 50DDGS diet (CON+CPVO). Steers were fed to a common 12th-rib fat depth endpoint (1.3 ± 0.2 cm; 68 to 125 d on trial). Loins and rounds were collected from 44 carcasses for Warner-Bratzler shear force (WBSF), ether extract, and case-life analyses. Data were analyzed using the MIXED procedure of SAS. Contrasts between 1) CON vs. elevated CP diets (50DDGS, CON+CP, and CON+CPVO; EP), 2) CON vs. elevated fat diets (50DDGS, CON+VO, and CON+CPVO; EF), and 3) CON vs. diets with elevated CP and fat (50DDGS and CON+CPVO; EPF) were analyzed. There were no differences in days on feed or DMI among treatments. Steers fed CON had greater ADG (P ≤ 0.03) than EP, EF, and EPF diets. Steers fed CON also had greater G:F (P ≤ 0.04) than EP and EPF steers. Final BW was greater for CON than EP and EPF diets (P ≤ 0.03). Likewise, CON steers had heavier HCW than EPF steers (P = 0.04). Dressing percent, 12th-rib fat depth, LM area, KPH, and yield grade were not affected by treatment (P ≥ 0.06). Steers fed the CON diet had greater marbling scores (P ≤ 0.03) and quality grades (P ≤ 0.02) compared with those fed EP, EF, and EPF diets. There were no differences in WBSF, ether extract, or lipid oxidation due to treatment (P ≥ 0.44). However, CON steers had greater (P = 0.02) L\textsuperscript* values than EF-fed steers and greater b\textsuperscript* values than EP, EF, and EPF steers (P ≤ 0.02) during retail display of ground product. Data from this study illustrate that live animal performance, marbling and quality grade, and color stability of ground product during retail display are negatively affected when DDGS are increased from 25 to 50% of the diet DM. This response appears to be due to elevated dietary fat, elevated CP, and a combination of elevated fat and protein within the diet.

Key words: distillers grain, feedlot, marbling, meat quality, steer

INTRODUCTION

Increased availability of distillers grains with solubles (DGS) in North America has led to considerable research on their effects on beef feedlot performance and carcass quality when fed as a CP source. Although little research has been performed on the utilization of DGS as a primary energy source, recent increases in corn prices, ethanol production, and DGS availability have resulted in utilization of DGS as such. Beef cattle fed finishing diets containing up to 40% wet DGS (WDGS) have had greater DMI, ADG, and G:F (Larson et al.,
Animals and Diets

were due to elevated dietary fat, elevated CP, or a combination of both. Therefore, our objectives were to 1) evaluate the effects of feeding elevated levels of DDGS to finishing steers on feedlot performance, carcass characteristics, and meat quality; and 2) determine if differences in the described areas are still in question at lesser inclusion rates.

Corah and McCully (2006) reported a decrease in marbling scores when DGS were fed at greater than 30% of DM; however, increased yield grades were noted at all inclusion levels of DGS. Decreased carcass quality may be due to reduced dietary starch content, which can ultimately influence marbling score (Smith and Crouse, 1984). Although decreased carcass quality may be partially explained by decreased starch intake, we hypothesized that feeding elevated levels of DDGS to finishing steers would negatively affect feedlot performance and carcass quality due to excessive levels of CP, dietary fat, or a combination of both. Therefore, our objectives were to 1) evaluate the effects of feeding increased levels of DDGS to finishing steers on feedlot performance, carcass characteristics, and meat quality; and 2) determine if differences in the described areas were due to elevated dietary fat, elevated CP, or a combination of elevated fat and protein within the diet.

MATERIALS AND METHODS

All procedures involving animals during the study were approved by the Purdue Animal Care and Use Committee before the initiation of research.

Animals and Diets

Before initiation of the trial, all steers were fed a common 13% CP growing diet consisting primarily of corn and corn silage for approximately 120 d. At the conclusion of the growing phase, 105 Angus-cross steers (443 ± 20 kg) were stratified and blocked by BW in a randomized complete block design to evaluate the effects of feeding DDGS during the finishing phase. Steers were adapted to finishing diets over a 21-d period. Initial BW of steers was determined by averaging individual BW obtained before feeding on d 0 and 1. Steers were randomly assigned to pen (7 steers/pen; 3 pens/diet) and housed in a curtain-sided, slatted-floor finishing barn in 6.1 × 3.3 m pens. All steers were implanted with Revalor I-S (Intervet Inc., Millsboro, DE) on d 0, and feed was offered for ad libitum consumption once daily at 0800 h with free access to water. One steer was removed from the study due to a nontreatment-related injury.

The 5 dietary treatments (Table 1), which were formulated to be isocaloric on a NE basis and to meet or exceed the NRC (2000) requirements of a finishing steer, were 1) a corn-based diet with DDGS included at 25% of DM (CON), 2) CON with DDGS included at 50% of DM (50DDGS), 3) CON with corn protein added in the form of gluten meal to equal the CP of the 50DDGS diet (CON+CP), 4) CON with added vegetable oil (soybean oil) to equal the ether extract content of the 50DDGS (CON+VO), and 5) CON with corn protein and vegetable oil (soybean oil) added to equal the CP and ether extract content of the 50DDGS (CON+CPVO). Diets CON+CP, CON+VO, and CON+CPVO were formulated to determine if potential differences in performance and carcass quality associated with feeding increased DDGS are due to increased dietary CP, increased levels of dietary fat, or a combination of elevated levels of CP and dietary fat. It should be noted that although diets were not balanced for degradable and undegradable intake protein, the undegradable intake protein for all diets ranged between 45 and 50% of CP.

Proximate Analysis

Feed refusals were weighed, recorded, and discarded. Individual feed ingredients were analyzed weekly for DM to adjust diet composition for ingredient moisture content. Composite feed samples were collected weekly and dried in a forced air oven at 60°C for 48 h for analysis of DM. Dried samples were ground to pass a 1-mm screen (Dietz-Motoren GmbH & Co. model WRB 90LB/4P, Dettingen, Germany) and analyzed for ether extract, ash (AOAC, 1990), and NDF and ADF (Ankom, Fairport, NY). Nitrogen was determined by combustion (Leco Instruments Inc., St. Joseph, MI; 976.06, AOAC, 1990) and multiplied by 6.25 to obtain CP.

Performance and Carcass Data

Individual BW and 12th-rib subcutaneous fat measurements, taken via B-mode ultrasound (Aloka American Ltd., Wallingford, CT), were recorded on 28-d intervals to track performance and aid in selection for slaughter. To determine the effects of DDGS inclusion on carcass quality, individual steers were identified for slaughter when 12th-rib subcutaneous fat depths reached approximately 1.3 cm. However, no individual steers were allowed to remain on study in a pen; therefore, if all but 1 steer within a pen had reached 1.3 cm of 12th-rib fat depth, all steers were slaughtered regardless of the final fat depth of the animal. Final BW for each steer was determined using the average prefeeding BW from 2 consecutive days before shipping. A predetermined, random subsample of 44 steers was slaughtered at the Purdue University Meat Science Research and Education Center (West Lafayette, IN) for collection of loin and round samples to be analyzed for ether extract, Warner-Bratzler shear force (WBSF), and case-life analyses. Remaining steers were slaughtered at a commercial packing facility (Tyson Fresh Meats Inc., Joslin, IL). Hot carcass weights were recorded immediately after evisceration at both facilities, and left side 12th-rib subcutaneous fat depth, LM area, KPH,
preliminary yield grades, marbling scores, and quality grades were collected by trained personnel after a 36-h chill. Final yield grade was calculated using the formula reported by Aberle et al. (2001).

Plasma Urea-N

Beginning at 0700 h on d 63, 91, and 119, preprandial blood samples were collected from all steers via jugular venipuncture into 10-mL heparinized Vacutainer (Becton, Dickinson and Co., Franklin Lakes, NJ) tubes. Blood samples were immediately refrigerated for 18 h at 0°C and centrifuged at 2,500 × g for 30 min at 4°C. Two aliquots of plasma (approximately 3 mL each) were obtained and transferred to 5-mL polystyrene tubes and stored at −20°C. Preprandial plasma samples were analyzed for plasma urea-N (PUN) concentrations using a commercial kit (Urea Nitrogen Procedure No. 0580, Stanbio Laboratory, Boerne, TX), with intra- and interassay CV of 8.2 and 4.7%, respectively. Samples were read on a DU 640 UV-Visible Spectrophotometer (Beckman Instruments Inc., Fullerton, CA).

Meat Quality

Sample Collection. A subsample of 44 steers (n = 8 for CON; n = 9 each for 50DDGS, CON+CP, CON+VO, and CON+CPVO) was slaughtered at the Purdue University Meat Research and Education Center for collection of tissue samples to be utilized for ether extraction, WBSF, and case-life analyses. At 48 h postmortem, a section of the loin (20 cm in length, and posterior to the 12th rib) and a 2.5-kg section of the inside round were obtained from the right side of the carcass. Samples were cut, trimmed, vacuum packaged, wet aged for 7 d, and stored at −20°C. Frozen samples were transported to South Dakota State University for WBSF, ether extraction, case-life, and lipid oxidation analyses.

WBSF. Warner-Bratzler shear force values were determined according to standards set by the American Meat Science Association. Steaks were cooked on clamshell grills to a target internal temperature of 71°C. After cooling overnight, six 1.3-cm-diameter cores were removed from each steak, parallel to the muscle fiber orientation. A single, peak shear force measurement was obtained for each core using a WBSF machine (G-R Electric Manufacturing Company, Manhattan, KS). Individual-core, peak shear force values were averaged to assign a mean peak WBSF value to each steak.

Ether Extraction. Percentage crude fat was determined according to method 39.1.05a of AOAC (1990). A minced sample of each frozen steak was placed in a blender cup and powdered with liquid nitrogen. After 3 to 4 g of each powdered sample was placed in a thimble, approximately 8 g of sand (50 + 70 mesh white quartz, Sigma, St. Louis, MO) was added and mixed with a
spatula. Thimbles were then placed in 50-mL beakers and dried in a 125°C oven for 1.5 h. After drying, samples were extracted with petroleum ether using a Goldfisch fat extraction apparatus (Labconco model 35001, Kansas City, MO). The extracted fat from each sample was dried at 100°C for 30 min and weighed.

**Ground Product Case-life Stability.** Case-life stability was determined on ground product. Top rounds were coarse ground (6.4-mm plate), mixed, and reground (3.2-mm plate). Four 0.1-kg patties were prepared from each top round. Patties were then placed on polystyrene trays and overwrapped with an oxygen permeable polyvinyl chloride stretch-wrap. Patties were then randomly assigned to a display for 0, 1, 2, 3, 4, 5, or 6 d. Overwrapped patties were stored at 2°C under simulated retail display. Objective color was determined on 2-d intervals starting on d 0 utilizing a HunterLab MiniScan XE handheld spectrophotometer equipped with a 6-mm aperture (HunterLab Associates, Reston, VA). Samples were evaluated for the International Commission on Illumination (CIE) \(L^*\) (brightness; 0 = black, 100 = white), \(a^*\) (redness/greenness; positive values = red, negative values = green), and \(b^*\) (yellowness/blueness; positive values = yellow, negative values = blue) color values. All values for \(L^*\), \(a^*\), and \(b^*\) were determined by calculating the average of 3 readings obtained from randomly selected locations on the patty through the polyvinyl chloride film. Once appropriate display length had been met, patties were removed from retail display and frozen for future lipid oxidation determination.

**Lipid Oxidation.** Lipid oxidation was assessed utilizing fluorometric analysis (Jo and Ahn, 1998). A minced sample of each frozen steak was placed in a blender cup and powdered with liquid nitrogen. After 1.0 g of each powdered sample was placed in 50-mL tubes, 9 mL of deionized distilled water and 50 μL of 7.2% butylated hydroxytoluene were added. Each sample was weighed in duplicate. Samples were then homogenized (UltraTurrax T25, Janke and Kunkel GmbH & Co., Staufen, Germany) on high speed for 30 s. After adding 0.5 mL of the homogenate to a 15-mL tube, 50 μL of butylated hydroxytoluene (7.2%) was added and samples were vortexed. Then, 200 μL of SDS (8.1%), 1.5 mL of 0.5 M HCl, 1.5 mL of thymidine 5′-monophosphate (20 mM), and 250 μL of deionized distilled water were added to the sample tubes. Samples were revortexed and heated in a water bath (90°C) for 15 min. After cooling for 10 min, 1 mL of deionized distilled water and 5 mL of n-butanol-pyridine (15:1; vol/vol) were added. Samples were mixed thoroughly for 5 min and then centrifuged (3,000 × g) for 15 min at 4°C. Thiobarbituric acid reactive substances (TBARS), measured in milligrams of malonaldehyde per kilogram of muscle, were determined using a fluorometer (Thermo Spectronic Amino-Bowman Series 2 Luminescence, Madison, WI) with 515 nm excitation and 550 nm emission.

**Statistical Analyses**

Performance and carcass characteristics data were analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC) for a randomized complete block design. The fixed effect of treatment was included in the model, with pen serving as the experimental unit and block as the random effect. The 2-way interaction of treatment × block was initially included in the statistical model and subsequently removed if not significant \((P > 0.05)\). The GLIMMIX procedure of SAS was used to analyze the proportion of cattle in each pen grading USDA Choice or greater. Additionally, the following contrasts were used to test treatment effects: 1) CON diet vs. the average of diets containing elevated CP levels (CON+CP, CON+CPVO, and 50DDGS; \(EP_F\)), 2) CON diet vs. the average of diets containing elevated fat levels (CON+VO, CON+CPVO, and 50DDGS; \(EF\)), and 3) CON diet vs. the average of diets containing elevated CP and fat levels (CON+CPVO and 50DDGS; \(EP_F\)).

Plasma urea-N data were analyzed as a single repeated measure within the MIXED procedure. The model included the fixed main effects of treatment and day, as well as the treatment × day interaction, with day serving as the repeated measure. In addition to the 3 contrasts described for performance and carcass characteristics data, linear and quadratic contrasts were used to test the main effects of day of sampling. Warner-Bratzler shear force and ether extract data were analyzed using the MIXED procedure of SAS with animal as the experimental unit and treatment as a fixed effect. Ground beef case life data (TBARS and \(L^*, a^*, b^*\)) were analyzed using a multivariate repeated measures analysis of the MIXED procedure with animal as the experimental unit, treatment as a fixed effect, and display day as the repeated measure. The same 3 contrasts described for performance and carcass characteristics data were used to evaluate treatment responses of WBSF, ether extract, and case-life data. Contrasts were considered significant when the \(F\)-test was ≤0.05, with an \(F\)-test of ≤0.10 considered as a tendency approaching significance.

**RESULTS AND DISCUSSION**

**Performance**

Although there were no differences in days on feed due to dietary treatment \((P = 0.77\) to 0.99; Table 2), a treatment × block interaction for days on feed was observed \((P < 0.001\); tabular data not shown). This was due to lighter BW blocks from the CON+VO treatment taking a greater number of days to reach a common fat depth endpoint. It is generally accepted that steers exhibiting a heavier initial BW, and therefore greater initial 12th-rib fat, will accrue subcutaneous fat more quickly, resulting in fewer days to a common
12th-rib fat endpoint than cattle with a lighter initial BW. However, light BW blocks from the CON+VO treatment may have taken longer to finish due to elevated dietary fat having a prolonged negative effect on ruminal fermentation. To our knowledge, however, there are no published data on time required to finish steers to a common fat depth endpoint due to varying dietary levels of DDGS. Likewise, DMI did not differ among treatments \((P = 0.14 \text{ to } 0.16)\). Others have reported similar results in DMI due to dietary inclusion of up to 40\% (Ham et al., 1994; Buckner et al., 2008) and 60\% DDGS (Gordon et al. 2002) as well as 40\% WDGS (Vander Pol et al., 2009). Conversely, Vander Pol et al. (2005) reported a quadratic response in DMI with inclusion of up to 50\% WDGS in the diet of finishing yearling steers.

Steers fed EP \((P = 0.008)\), EF \((P = 0.03)\), and EPF \((P = 0.005)\) diets had lesser ADG compared with CON. These differences in ADG, coupled with no differences in days on feed, resulted in lighter final BW for EP \((P = 0.03)\) and EPF \((P = 0.02)\) diets, and tended to reduce \((P = 0.09)\) final BW in steers fed EF diets compared with CON-fed steers. Additionally, a treatment \(\times\) block interaction \((P = 0.03; \text{tabular data not shown})\) for final BW was noted. This was due to light BW blocks from 50DDGS and CON+CPVO diets having lighter BW cattle at the time of slaughter when taken to a common backfat endpoint, which is also related to the lighter BW blocks of CON+VO cattle taking longer to reach their endpoint, as previously discussed, and therefore having heavier final BW.

Steers fed EP and EPF diets had lesser G:F \((P = 0.04 \text{ and } 0.03, \text{respectively})\), whereas those fed EF diets only tended \((P = 0.09)\) to have lesser G:F relative to CON-fed steers. These data are similar to that of Gordon et al. (2002), who reported a linear decrease in G:F with increased dietary DDGS levels, and to that of Vander Pol et al. (2005), which depicted a quadratic response in G:F with increased concentrations of WDGS in the diet. However, contrasting data have shown an increase in G:F of finishing steers fed up to 40\% DDGS in conjunction with dry-rolled corn (Corrigan et al., 2007), which was a diet similar to the diets used in our study.

It should be noted that differences in performance associated with WDGS and DDGS discussed in previous studies may be attributed to not only variation in digestibility and chemical composition associated with ethanol plant protocol (i.e., level of soluble inclusion, drying temperatures, and drying times) used in the production of these by-products, but also the way in which cattle were selected for slaughter as performance variables may be altered if cattle are fed to a common BW, common number of days on feed, or common 12th-rib fat depth. Cattle in this study were taken to a common backfat depth. In the current study, however, reduction in feedlot performance associated with increased dietary DDGS appears to be due in part to excessive dietary CP. In a review by Owens et al. (1995), it was concluded that the poor efficiency in which excess protein is converted to fat may lead to excesses of escape or microbial protein being of less value than carbohydrate or protein that is degraded within the rumen. This may at least partly explain the adverse effects of excess dietary protein on performance (Tyrrell et al., 1970; Garrett, 1980). Additionally, these data demonstrate that increased fat concentrations from diets containing elevated levels of DDGS tend to reduce performance during the finishing phase, which may be due in part to a negative associative effect of dietary fat on rumen fermentation (Brooks et al., 1954). It should be noted that the added fat diets contained soybean oil rather than corn oil, which have a different fatty acid profile and potentially could have differing effects on fiber digestion. However, differences that occur between the diets with added oil and the 50DDGS diet are likely due to partial protection of the lipid in the 50DDGS diets compared with added free oil (Klopfenstein et al., 2008). These data suggest that combination of both of these scenarios is likely because this study suggests a

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Table 2. Effects of differing levels of CP and fat from dried distillers grains with solubles (DDGS) on performance characteristics and circulating plasma urea-N concentrations of finishing steers

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment (^1)</th>
<th>SEM(^2)</th>
<th>Contrast (P)-value(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON</td>
<td>50DDGS</td>
<td>CON+CP</td>
</tr>
<tr>
<td>Days on feed</td>
<td>95</td>
<td>95</td>
<td>96</td>
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<tr>
<td>Initial BW, kg</td>
<td>444</td>
<td>444</td>
<td>443</td>
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<tr>
<td>Final BW, kg</td>
<td>595</td>
<td>582</td>
<td>583</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>10.15</td>
<td>9.88</td>
<td>9.75</td>
</tr>
<tr>
<td>ADG, kg</td>
<td>1.62</td>
<td>1.43</td>
<td>1.48</td>
</tr>
<tr>
<td>G:F, kg/kg</td>
<td>0.160</td>
<td>0.146</td>
<td>0.152</td>
</tr>
<tr>
<td>Urea-N, mg/dL</td>
<td>9.92</td>
<td>12.96</td>
<td>14.04</td>
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</tbody>
</table>

\(^1\)CON = 25\% DDGS; 50DDGS = 50\% DDGS; CON+CP = control + corn protein; CON+VO = control + vegetable oil; CON+CPVO = control + corn protein and vegetable oil.

\(^2\)The greatest SEM is presented (performance variables: \(n = 15\) for CON, 50DDGS, CON+CP, and CON+CPVO; \(n = 14\) for CON+VO; Urea-N: \(n = 41\) for CON, \(n = 38\) for 50DDGS and CON+CPVO, \(n = 35\) for CON+CP, \(n = 43\) for CON+VO).

\(^3\)EP = CON vs. elevated CP diets (50DDGS, CON+CP, and CON+CPVO), EF = CON vs. elevated fat diets (50DDGS, CON+VO, and CON+CPVO), and EPF = CON vs. diets containing elevated CP and fat (50DDGS and CON+CPVO).
reduction in performance of cattle fed diets containing a combination of elevated CP and dietary fat.

**PUN**

A treatment × day interaction ($P = 0.008$; Figure 1) was observed for circulating PUN concentration. Whereas EP diets had similar PUN concentrations on d 91 ($P \geq 0.38$) and d 119 ($P \geq 0.13$), CON+VO fed steers were similar ($P = 0.72$) to 50DDGS fed steers and greater ($P = 0.03$) than CON fed steers on d 63. Circulating PUN concentrations in EP, EF, and EPF steers were greater ($P < 0.001$) than in CON steers (Table 2). However, these data are somewhat skewed because PUN concentrations were numerically greatest in CON+CPVO steers and this diet was included in all contrasts. Steers fed EP diets exceeded CP requirements of finishing steers, and therefore, greater circulating PUN rates were expected. Contradictory to most published data (Thomson et al., 1995; Cole et al., 2003, 2006), however, PUN concentrations decreased linearly ($P < 0.001$) over day of sampling. This decrease may be attributed to a linear increase in BW ($P = 0.002$; tabular data not shown) between days of sampling without an associated increase in DMI ($P = 0.55$; tabular data not shown). Therefore, a constant intake of nitrogen, during a phase of increased BW gain, likely resulted in decreased nitrogen intake per unit BW resulting in decreased PUN between days of sampling. These data suggest that feeding 50% DDGS in the diet of finishing cattle significant increases PUN concentrations compared with diets containing 25% DDGS.

**Carcass Characteristics**

No differences were detected in dressing percentage ($P = 0.93$ to 1.00) due to dietary treatment (Table 3). This, coupled with differences in final BW, led to expectations of differences in HCW that would mimic those of the final BW. Steers fed the CON diet did have heavier HCW than EPF steers ($P = 0.04$), but only tended ($P = 0.06$) to have heavier HCW than EP steers, and did not differ ($P = 0.13$) from EF-fed steers. By design, there were no differences in 12th-rib fat depth ($P = 0.09$ to 0.49) because cattle were slaughtered to minimize differences in back fat. It should be noted that EF-fed steers tended to have reduced 12th-rib fat depth ($P = 0.09$) when compared with CON steers. This is likely due to 1 outlier in each of the CON+VO and CON+CPVO treatments, which had 12th-rib fat depths of 0.69 and 0.74 cm, respectively, at the time of pen close-outs. Additionally, no differences in LM area ($P = 0.86$ to 0.97) or KPH ($P = 0.71$ to 1.00) were noted due to dietary treatment. Final calculated yield grade tended to be less in EF ($P = 0.06$) and EPF ($P = 0.08$) steers when compared with CON. This is likely because the 50DDGS, CON+VO, and CON+CPVO treatments, which comprise the EF and EPF contrast groups, had less numerical 12th-rib fat depth at the time of slaughter when compared with CON and CON+CP treatments. These carcass characteristics parallel those found by Gordon et al. (2002), who also reported no differences in dressing percentage, LM area, or KPH; however, the aforementioned data set found linear and quadratic decreases in HCW with increasing levels of DDGS in the diet.
Table 3. Effects of differing levels of CP and fat from dried distillers grains with solubles (DDGS) on carcass characteristics in finished steers

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>SEM</th>
<th>Contrast P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCW, kg</td>
<td>CON</td>
<td>369.1</td>
<td>360.3</td>
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<tr>
<td>Dressing percent</td>
<td>CON</td>
<td>62.0</td>
<td>62.3</td>
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<tr>
<td>Fat thickness, cm</td>
<td>CON</td>
<td>1.33</td>
<td>1.23</td>
</tr>
<tr>
<td>LM area, cm²</td>
<td>CON</td>
<td>81.3</td>
<td>80.7</td>
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<tr>
<td>KPH, %</td>
<td>CON</td>
<td>2.21</td>
<td>2.21</td>
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<tr>
<td>Yield grade</td>
<td>CON</td>
<td>3.33</td>
<td>3.18</td>
</tr>
<tr>
<td>Marbling score</td>
<td>EP</td>
<td>613</td>
<td>568</td>
</tr>
<tr>
<td>Quality grade</td>
<td>EF</td>
<td>17.67</td>
<td>17.29</td>
</tr>
<tr>
<td>USDA Choice or Prime, %</td>
<td>EPF</td>
<td>90.5</td>
<td>85.7</td>
</tr>
</tbody>
</table>

1 CON = 25% DDGS; 50DDGS = 50% DDGS; CON+CP = control + corn protein; CON+VO = control + vegetable oil; CON+CPVO = control + corn protein and vegetable oil.
2 The greatest SEM is presented (n = 15 for CON, 50DDGS, CON+CP, and CON+CPVO; n = 14 for CON+VO).
3 EP = CON vs. elevated CP diets (50DDGS, CON+CP, and CON+CPVO), EF = CON vs. elevated fat diets (50DDGS, CON+VO, CON+CPVO), and EPF = CON vs. diets containing elevated CP and fat (50DDGS and CON+CPVO).
4 Marbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, etc.
5 Quality grade: 15 = Select−, 16 = Select+, 17 = Choice−, 18 = Choice+, etc.

No differences (P = 0.15 to 0.31) were detected in the percentage of cattle obtaining a quality grade of USDA Choice or Prime. However, steers fed the CON diet had greater marbling scores and quality grade scores compared with steers fed EP (P = 0.03 and 0.02, respectively), EF (P = 0.03 and 0.02, respectively), or EPF diets (P = 0.01 and 0.01, respectively). These results in marbling score are similar to data presented by Reinhardt et al. (2007) that illustrate declining marbling scores when DGS are added at 23% of the diet DM or greater. Reduction in marbling score, and consequently quality grade, could be due to decreased dietary starch (Smith and Crouse, 1984; Choat et al., 2003). Those studies concluded that diets greater in starch promote intramuscular fat deposition relative to subcutaneous fat deposition. Furthermore, increasing the DDGS fraction of the diet not only reduces total dietary starch intake, but also results in decreased digestibility of starch derived from other ingredients (i.e., corn; Pingel and Trenkle, 2006). Steers fed CON in the current study graded exceptionally well, averaging Modest levels of marbling (score of 613), and 90.5% of the carcasses graded Choice or Prime. However, a combination of elevated CP and fat levels in the diet reduced marbling scores by 11.4% (70 points) and quality grade scores by over 0.5 units, but did not reduce the percentage of carcasses grading Choice or Prime when compared with CON-fed steers. This is of particular interest because over one-third of all carcass reported in the 2000 National Beef Quality Audit from nearly 53% to approximately 32%. Consequently, the impact of feeding finishing steers diets containing 50% DDGS could cause significant financial damage based solely on carcass merit if the cattle are genetically the industry average for marbling.

**Cost Analysis**

A crude cost performance analysis was performed only between CON and 50DDGS diets due to little practicality of feeding ingredients found in the 3 remaining diets. Assuming a commodity market of $0.197/kg for corn (as fed) and $0.154/kg for DDGS (as fed), CON steers had an average daily feed cost of $1.88 compared with $1.71 for 50DDGS steers. Although this is a 9% reduction in daily feed cost, it should be noted that this value is in part due to the 3% reduction in average daily DMI for 50DDGS. However, when taking into account the cost of each kilogram of BW gain, 50DDGS steers would be 3% more expensive at $1.20/kg of BW gain compared with $1.16/kg of BW gain for CON-fed steers. The better cost of BW gain for CON-fed steers can be associated with the 13% greater ADG and 9% better G:F for CON-fed steers. When operating in a market where corn prices are $0.276/kg (as fed) and DDGS are $0.198/kg (as fed), the daily cost of feed increases to $2.56 for CON compared with only $2.28 for 50DDGS. In contrast, differential cost of BW gain between the 2 diets decreases dramatically, as both diets cost $1.58/kg of BW gain. Therefore, these data suggest that feeding elevated levels of DDGS to finishing steers from a cost of BW gain perspective is only economically sensible when commodity markets are extremely inflated. However, it is also important to consider price spreads between corn and DDGS, live cattle pricing, and grid pricing premiums and discounts when determining what level of DDGS in finishing diets of steers is optimal to obtain maximal profit.
**Meat Quality Characteristics**

No differences in WBSF evaluation were identified among treatments (P = 0.46 to 0.89; Table 4). Similar WBSF results were reported by Roeber et al. (2005) and Gill et al. (2008) in cattle fed varying levels of DDGS. Although reports of consumer threshold for tenderness acceptability measured by WBSF are highly variable, it is important to note that only steers fed CON+CP and CON+CPVO obtained WBSF values that were within the consumer acceptability thresholds reported by Shackelford et al. (1991). Additionally, there were no differences in crude fat percentage (P = 0.66 to 0.99; Table 4) from strip steaks, but the steers fed CON+CPVO had the smallest numerical crude fat percentage, which corresponds with decreased numerical marbling scores within that treatment. However, it is important to note that not all ether extract values were consistent with marbling data. This could be because marbling data were collected from the left side of the carcass and samples used in ether extraction were obtained from the right side of the carcass. It is also of merit to note that only a subset of steers was used for analysis of meat quality characteristics. It is possible that the random subset used for these analyses was not representative of the entire group of animals on trial.

There were no treatment × duration of retail display interactions (P ≥ 0.44) for case-life analyses; therefore, only main effects will be reported for retail display results. Thiobarbituric acid reactive substances from ground top round samples did not differ due to dietary treatment (P = 0.44 to 0.50; Table 4). However, as expected, TBARS increased linearly in relation to day of display (P < 0.001; tabular data not shown). Although L* values did not differ due to duration of retail display (P = 0.78; Table 4), steers fed EF diets had darker ground top round (less L* value; P = 0.02) than CON-fed steers. Conversely, Roeber et al. (2005) found no differences in L* values of strip steaks from dairy steers fed 25 or 50% DDGS. However, similar to the current study, Hutchison et al. (2006) reported darker steaks from steers fed increased levels of fat, although fat sources in that study were tallow or poultry fat. Ground samples were less red (less a* value; P < 0.001) and yellow (less b* value; P < 0.001) on d 6 of retail display when compared with d 0. Furthermore, a* and b* values decreased linearly (P < 0.001) relative to day of retail display, which is again similar to that reported by Hutchison et al. (2006). Additionally, steers fed the CON diet tended to have redder patties (greater a* values) when compared with EP (P = 0.10) and EPF (P = 0.08) steers, which is similar to Roeber et al. (2005) who noted linear decreases in a* values of dairy steers fed increasing concentrations of DDGS. Steers fed CON also produced patties that were more yellow (greater b* value) than EP (P = 0.02), EF (P = 0.01), and EPF (P = 0.02) steers.

Data from this study illustrate that live performance, marbling scores, quality grades, and color stability of ground product during retail display were negatively affected when DDGS increased from 25 to 50% of the diet (DM basis). This response appears to be related not only to increased CP or fat concentrations within the diet of steers fed elevated levels of DDGS, but also to a combination effect of elevated concentrations of CP and fat within these diets. However, diets containing 50% DDGS do not appear to negatively affect meat quality characteristics such as tenderness and lipid oxidation of ground product when compared with diets containing 25% DDGS.

**LITERATURE CITED**


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**Table 4. Effects of differing levels of CP and fat from dried distillers grains with solubles (DDGS) on meat quality characteristics in finished steers**

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment1</th>
<th>Contrast P-value3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CON 50DDGS</td>
<td>CON+CP</td>
</tr>
<tr>
<td>Warmer-Bratzler shear force, kg</td>
<td>4.92</td>
<td>4.86</td>
</tr>
<tr>
<td>Ether extract, % of DM</td>
<td>5.59</td>
<td>6.10</td>
</tr>
<tr>
<td>TBARS, mg of malonaldehyde/k of muscle1</td>
<td>3.77</td>
<td>4.53</td>
</tr>
<tr>
<td>Instrumental color analysis5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L*</td>
<td>53.92</td>
<td>53.16</td>
</tr>
<tr>
<td>a*</td>
<td>16.55</td>
<td>15.42</td>
</tr>
<tr>
<td>b*</td>
<td>14.55</td>
<td>13.56</td>
</tr>
</tbody>
</table>

1CON = 25% DDGS; 50DDGS = 50% DDGS; CON+CP = control + corn protein; CON+VO = control + vegetable oil; CON+CPVO = control + corn protein and vegetable oil.

2The greatest SEM is presented (n = 9 for 50DDGS, CON+CP, CON+VO, and CON+CPVO; n = 8 for CON).

3EP = CON vs. elevated CP diets (50DDGS, CON+CP, and CON+CPVO), EF = CON vs. elevated fat diets (50DDGS, CON+VO, and CON+CPVO), and EPF = CON vs. diets containing elevated CP and fat (50DDGS and CON+CPVO).

4Thiobarbituric acid reactive substances measured in milligrams of malonaldehyde per kilogram of top round muscle.

5International Commission on Illumination L* brightness (0 = black, 100 = white); a* redness/greenness (positive values = red, negative values = green); b* yellowness/blueness (positive values = yellow, negative values = blue) values recorded from ground, top round patties.


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