**Project Title:** Effects of Dietary Fat and Crude Protein on Feedlot Performance and Carcass Characteristics in Steers Fed Differing Levels of Dried Distiller's Grains with Solubles

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## Background

Over the last decade, intensified ethanol production resulting in increased availability of distiller's grains with solubles (DGS) in the United States has led to considerable research on the effects of DGS on beef feedlot performance and carcass quality.

Gordon et al. (2002) reported increased DMI, ADG and feed efficiency in heifers fed finishing diets with inclusion of dried DGS (DDGS) at 50% of the diet while Pingel and Trenkle (2006) reported that DDGS have a higher relative feed value than corn when included at 20% of the diet. Greater performance is likely due to increased fiber digestion and oil content of the by-product. Whereas corn grains have relatively high starch content, DDGS have little starch remaining, leaving a highly fermentable carbohydrate source. However, increasing the DDGS fraction of the diet not only reduces total dietary starch intake, but it also has resulted in decreased digestibility of starch derived from other ingredients (i.e. corn; Pingel and Trenkle, 2006). Although feeding higher levels of DDGS apparently does not significantly affect live animal performance in the feedlot, their effects on carcass composition are still in question.

Increased yield grade has been reported with inclusion of DGS in the diet, regardless of level, while marbling score does not appear to be affected until DGS inclusion rates exceed 30% (Corah and McCully, 2006). This may be due to a reduction in starch content which can affect adipocyte proliferation and differentiation which can ultimately influence marbling score (Smith and Crouse, 1984). However, it has not been determined if level of dietary CP influences marbling through decreased energetic efficiency, or if dietary fat decreases performance in DMI and digestibility. Therefore, our objective was to evaluate the effects of dietary fat and crude protein on feedlot performance, carcass characteristics, meat quality and circulating concentrations of metabolites and hormones associated with nutrient utilization in finishing steers fed differing levels of DDGS.

## Methodology

*General*

All procedures involving animals during the study were approved by the Purdue Animal Care and Use Committee before the initiation of research. One-hundred-five Angus-cross steers (443 ± 31 kg) were used in a completely randomized design. Prior to initiation of the trial, all steers were fed a growing ration consisting primarily of corn and corn silage for approximately 120 d. At the conclusion of the growing phase, steers were adapted to their finishing diets over a 21 d period. On trial weights of steers were individually obtained on consecutive days (d 0 and d 1) and steers were implanted with Revalor I-S (Intervet, Inc., Millsboro, DE) on d 0. Steers were stratified



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by weight, assigned randomly to pen (7 steers/pen; 3 pens/diet), and housed in a curtain-sided, slatted- floor finishing barn in 6.1-m x 3.3-m pens. Feed was offered for ad libitum consumption once daily at 0800 with free access to water.

The five dietary treatments (Table 1), which were formulated to be isocaloric and to meet or exceed the NRC (2000) requirements of a finishing steer, were: 1) a corn-based diet with DDGS included to meet CP requirements (25% of DM; CON), 2) CON with DDGS included at twice the amount of CON (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 to equal the ether extract content of the 50DDGS diet (CON+VO), and 5) CON with corn protein and vegetable oil added to equal the CP and ether extract content of the 50DDGS diet (CON+CPVO). One steer was removed from the CON+VO treatment due to injury not related to treatment.

*Performance and Carcass Data*

Individual weights and 12th rib subcutaneous fat measurements by way of ultrasound (US) were recorded and measured on 28 day intervals to track performance and aid in harvest selection. In order to determine the effects of DDGS inclusion on carcass characteristics, steers were individually selected for harvest when 12th rib subcutaneous fat depths reached approximately 1.3 cm. No steers were allowed to remain on study as singles within a pen. Individual final BWs were determined using the average pre-feeding weight from two consecutive days prior to shipping. A sub-sample of 44 steers was harvested at the Purdue University Meat Research and Education Center (West Lafayette, IN) for collection of samples to be analyzed for fatty acid, ether extraction, Warner-Bratzler Shear and case-life analyses. The remaining steers were harvested at a commercial packing facility (Tyson Fresh Meats, Inc., Joslin, IL). Hot carcass weights were recorded immediately following evisceration at both harvest facilities, and 12th rib subcutaneous fat depth, LM area, KPH, preliminary yield grades and quality grades were collected by trained personnel following a 36-hour chill. Final yield grade was calculated using the formula reported by Aberle et al. (2001).

*Sampling and Laboratory Analyses*

**Feed.** Feed refusals were weighed, recorded and discarded daily. Individual feed ingredients were analyzed weekly for DM to adjust intake for dietary moisture content. Composite feed samples were dried in a forced air oven at 60ºC for 48h, ground to pass a 1-mm screen, and analyzed for DM, ether extract, ash (AOAC, 1990), NDF and ADF (ANKOM, Fairport, NY). Nitrogen was determined by combustion (Leco Instruments Inc., St. Joseph, MI; AOAC 976.06, 1990) and multiplied by 6.25 to obtain CP.

**Metabolites and hormones.** Beginning at 0700 on day 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. Steers were allowed 1 hour 45 min to consume feed and water, and then postprandial blood samples were collected on three steers selected at random from each pen (15 steers/diet; 45 steers total) beginning at 2 hours from the onset of feeding (0 hour) and collected at 2 hour intervals for 4 hours. The steers remaining on trial that had postprandial blood sampled on day 63 were again sampled on day 91 and 119, as described previously. Blood samples were immediately refrigerated for 18 h at 0ºC and centrifuged at 2,500 x g for 30 min. Two aliquots of plasma (3 mL each) were obtained and transferred to 5-mL polystyrene tubes and stored at -20ºC.

Preprandial plasma samples were analyzed for urea nitrogen 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-



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Visible Spectrophotometer (Beckman Instruments Inc., Fullerton, CA). Preprandial and postprandial plasma samples collected every 2 hours were analyzed for insulin using a commercially available RIA kit (Coat-A-Count Insulin, Siemens Medical Solutions USA Inc., Malvern, PA; intra- and interassay CV of 4.9 and 2.6%, respectively) and glucose (Glucose Liqui-UV (Hexokinase) Procedure No. 1060, Stanbio Laboratory, Boerne, TX; intra- and interassay CV of 7.4 and 8.6, respectively). The glucose determination procedure was modified utilizing a standard calibration curve consisting of 0, 50, 100, 125 and 250 mg of glucose/dL created from dilution of a 1000mg/dL glucose standard.

Also, sample preparation was modified by adding 3 µL of plasma to 300µL of reagent on 350µL, UV-transparent 96-well plates (Becton, Dickinson and Co., Franklin Lakes, NJ) and read on an Opsys MR microplate reader (Dynex Technologies Inc., Chantilly, VA) at 340 nm.

**Tissue samples.** A sub-sample of 44 steers was harvested at the Purdue University Meat Research and Education Center (West Lafayette, IN) for collection of samples to be utilized for fatty acid, ether extraction, Warner-Bratzler Shear Force and case-life analyses. Immediately following removal of the hide, a two inch section of longissimus muscle was obtained approximately between the 8th and 10th rib on the right side of the carcass. Subcutaneous fat was immediately trimmed, packaged in freezer-safe storage bags and frozen on dry ice. Samples remained frozen at -20ºC until initiation of fatty acid analysis conducted at Texas A&M University.

At 24 hours post-mortem, a 20 cm long section of the loin posterior to the 12th rib as well as a 2.5 kg section of the inside round was removed from the right side of the carcass, cut and trimmed, vacuum packaged, aged for 7 d, and frozen. Frozen samples were transported to South Dakota State University for case-life, lipid oxidation, Warner-Bratzler Shear Force (WBSF) and ether extraction analyses.

*Meat Quality*

**Warner-Braztler Shear Force.** WBSF was determined according to standards set by the American Meat Science Association. Steaks from each treatment were cooked on clam-shell grills to a target internal temperature of 71°C. After cooking cooled steaks overnight, six 0.5-inch-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, Kansas). Individual-core, peak shear force values were averaged to assign a mean peak WBSF value to each steak.

**Ground Product Case-life Stability.** Case-life stability was determined on ground product. Top rounds were coarse ground (6.4 mm plate), mixed and re-ground (3.2 mm plate). Four quarter- pound patties were prepared from each top round. Patties were then placed on polystyrene trays and over-wrapped with an oxygen permeable PVC stretch-wrap. Patties were then randomly assigned to a display for 0, 2, 4, or 6 days. Over-wrapped patties were stored at 2°C under simulated retail display for assigned display days. Each day (d 0 - d 6) objective color was determined utilizing a HunterLab MiniScan XE hand-held spectrophotometer equipped with a 6-mm aperture (HunterLab Associates, Reston, Virginia). Samples were evaluated for 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 three readings obtained from randomly selected locations on the patty through the PVC film. Once appropriate display length had been met, patties were removed from retail display and frozen for future lipid oxidation determination.



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**Ether Extraction.** Percent crude fat was determined according to standards set by the AOAC. A minced sample of each frozen steak was placed in a blender cup and powdered with liquid nitrogen. After 3-4 g of each powdered sample was placed in a thimble, a small amount of sand was added and mixed with a spatula. Thimbles were then placed in 50mL beakers and dried in a 125°C oven for 1.5 h. After drying, the thimbles were extracted with petroleum ether using a Goldfisch fat extraction apparatus (Labconco model 35001, Kansas City, Missouri). The extracted fat from each sample was dried at 100°C for 30 min and weighed.

**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 (DDW) and 50 µ of 7.2 % butylated hydroxytoluene (BHT) were added. Each sample was weighed in duplicate. Samples were then homogenized (Ultra Turrax T25, Janke and Kunkel GmbH & Co. Staufen, Germany) on high speed for 30 seconds. After adding 0.5 mL of the homogenate to a 15 mL tube, 50 µL of BHT (7.2%) was added and samples were vortexed. Then, 200 µL of SDS (8.1%), 1.5 mL of hydrochloric acid (0.5 M), 1.5 mL of TMP (20 mM), and 250 µL DDW were added to the sample tubes. Samples were vortexed and then heated in water bath (90°C) for 15 min. After cooling for 10 min, 1 mL of DDW and 5 mL of n-butonoal-pyridine (15:1, vol/vol) were added. Samples were mixed thoroughly for 5 min and then centrifuged (3000 x g) for 15 min. The amount of malonaldehyde in each sample was determined using a fluorometer (Thermo Spectronic Amino-Bowman Series 2 Luminescence, Madison, Wisconsin) with 515 excitation and 550 emission.

**Fatty Acid Profile.** Fatty acid analysis of subcutaneous adipose tissue was determined utilizing the procedure outlined in Huerta-Leidenz et al. (1996).

*Statistical Analyses*

Performance, carcass characteristics and fatty acid data were analyzed using the MIXED procedure of SAS (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 a random effect. Frequency distributions of USDA quality grades were analyzed using the GLIMMIX procedure of SAS for generalized linear mixed models. The statistical model used for this analysis included the fixed effect of treatment and block as a random effect. The following orthogonal 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), and 2) CON diet vs. the average of diets containing elevated fat levels (CON+VO, CON+CPVO, and 50DDGS).

Glucose and insulin data obtained from intensive blood samples were analyzed as repeated measures and the model included the effects of treatment, day, and time of sampling. The day × time interaction was significant for glucose and was included in the model. Sampling time was used as the repeated effect, and steer nested within treatment × day was used as the subject. As plasma urea nitrogen data was not collected intensively, the model only contained the fixed effects of treatment, day and the treatment × day interaction utilizing steer nested within 7 treatment × day as the random effect. The same two contrasts utilized for performance and carcass data were again used for plasma data.

WBSF and ether extract data were analyzed using PROC GLM procedure of SAS with animal as the experimental unit and diet as a fixed effect. Ground beef case life data (TBARS and L*, a*, b*) were analyzed using a multivariate repeated measures analysis (REPEATED option of PROC GLM) with animal as the experimental unit, diet as a fixed effect, and display day as the repeated measure.



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## Findings

*Performance*

There were no differences in days on feed ($P = 0.71$), DMI ($P = 0.14$), or G:F ($P = 0.11$; Table 1) due to dietary treatment. To our knowledge, there is no published data on the effects of DDGS and the time required to finish steers to a common fat depth. However, others have reported similar results for DMI and feed efficiency due to dietary inclusion of up to 40% DDGS (Buckner et al., 2007; Ham et al. 1994). In contrast, Vander Pol et al. (2007) reported linear decreases in both DMI and G:F with inclusion of up to 50% wet DGS (WDGS) in the diet of finishing yearling steers. It should be noted that differences between WDGS and DDGS may be attributed to variation in both digestibility and ethanol plant protocol associated with the production of these by-products.

Steers fed the CON treatment displayed a greater ($P = 0.04$) ADG than 50DDGS fed steers. Additionally, steers fed diets with increased levels of CP and fat had a decreased ADG ($P = 0.01$ and 0.03, respectively), without a difference in DMI, G:F, or days on feed. This resulted in lighter ($P = 0.04$) final body weights when compared with CON fed steers. Reduced performance in the elevated CP and fat diets could be attributed to a negative associative effect of increased fat on fiber digestion and as excess N in the diet being energetically less efficient.

*Carcass Characteristics*

No differences were detected in dressing percent ($P = 0.77$) due to dietary treatment (Table 3). The lack of dressing percent differentiation, coupled with the differences stated previously in final BW, led to expectations of differences in HCW. However, CON and CON+VO fed steers only tended ($P = 0.08$) to be heavier than CON+CPVO steers. There were also no differences in 12th rib fat depth ($P = 0.12$), LM area ($P = 0.99$), KPH ($P = 0.87$) or final calculated yield grade ($P = 0.16$) due to dietary treatment (Table 3). Because cattle were harvested at approximately 1.3 cm of 12th rib fat depth, no differences were expected or observed. Also, noting no differences in any of the constituents that determine final yield grade, no differences in its calculation were expected or observed.

Steers fed the CON diet had both greater marbling scores and quality grade scores compared with steers fed either the elevated CP ($P = 0.02$ and 0.03, respectively) or fat diets ($P = 0.02$ and 0.03, respectively), however, no differences ($P = 0.25$) were detected in the percentage of cattle obtaining a quality grade of USDA Choice or Prime. Steers fed the CON treatment graded very well averaging modest levels of marbling (score of 612.9) and 90.5% grading either choice or prime.

Elevated CP and fat levels in the diet reduced marbling scores over 0.33 units, but did not significantly reduce the percentage of carcasses grading choice or prime.

*Metabolites and Hormones*

A day × time sampling interaction ($P = 0.001$) was noted for circulating plasma concentration of glucose (Figure 1). Preprandial glucose concentrations on day 63 were greater ($P < 0.0001$) than all other sampling times. Additionally, glucose concentrations taken 2 hours, 4 hours and 6 hours postprandially on day 119 were less than ($P < 0.003$) all sample times on day 63. Main effects of treatment were not noted for plasma glucose ($P = 0.73$; Table 4). However, main effects of day were greater ($P < 0.001$) for circulating concentrations of plasma glucose on day 63 when compared with day 91 and day 119. In addition, main effects of time of sampling were greater ($P < 0.0001$) for preprandial and 6 hour samples when compared with 2 hour and 4 hour samples (Table 5).

There were no differences in circulating concentrations of plasma insulin due to main effects of treatment ($P = 0.50$), day ($P = 0.95$), or treatment × day interaction ($P = 0.74$). However, insulin levels decreased over time ($P < 0.001$) in relation to feeding within sampling day.



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Increased levels of insulin preprandially are likely in response to increased levels of glucose preprandially, while decreased levels of insulin 6 hours postprandial may be due to a lag effect between glucose circulation and pancreatic release of insulin.

A treatment × day interaction ($P = 0.008$; Figure 2) occurred for plasma urea nitrogen (PUN) concentration. While all diets containing increased levels of CP had similar PUN concentrations on both day 91 ($P > 0.38$) and day 119 ($P > 0.13$), CON+VO fed steers were similar to 50DDGS fed steers ($P = 0.72$) on day 63. Furthermore, CON+CPVO steers had greater ($P<0.001$) PUN concentrations when compared with CON, 50DDGS, and CON+VO steers (Table 4). Additionally, 50DDGS and CON+CP steers had greater concentrations of PUN when compared with CON and CON+VO fed steers. Diets containing increased levels of CP exceeded the CP requirements of finishing steers and therefore, greater circulating PUN rates were expected because all nitrogen could not be utilized by the steer for tissue deposition. Also, PUN concentrations decreased linearly ($P <0.001$) over day of sampling. This decrease may be attributed to an increase in BW without concomitant increase in intake. Steers had reached a plateau of intake prior to sampling on day 63. However, BW increased between sampling periods while nitrogen intake remained constant, resulting in a decrease in nitrogen intake per unit BW, thus resulting in decreased PUN.

*Meat Quality Characteristics*

No differences in objective tenderness evaluation were identified among treatments (Table 6). Similar WBSF results were reported by Roeber et al. (2005) and Gill et al. (2008) in cattle fed varying levels of DDG. Additionally, there were no differences in crude fat percentage (Table 6) from strip steaks, however the CON+CPVO fed steers tended to have the lowest crude fat percentage, which corresponds with lower marbling scores. Dietary treatment did not affect case life of ground beef patties as indicated by malonaldehyde concentration (Figure 3), or a*, L*, or b* values (Figure 4).

Subcutaneous adipose tissue concentrations of fatty acids 14:0 ($P =0.39$), 14:1 ($P =0.65$), and 16:0 ($P =0.21$; Table 7), which are synthesized by de novo synthesis, were not different due to dietary treatment. However, 16:1 concentrations were greater ($P = 0.04$) in CON, CON+CP and CON+VO fed steers when compared with CON+CPVO. In addition, steers fed elevated fat diets tended ($P = 0.07$) to have lesser concentrations of 16:1 than CON fed steers. Stearic acid concentrations were greater ($P = 0.04$) in 50DDGS and CON+CPVO steers when compared with CON+CP fed steers, and furthermore CON+CPVO steers had greater concentrations of 18:0 when compared with CON and CON+VO fed steers. Steers on CON and CON+VO diets were intermediate to 50DDGS and CON+CP steers. While there were no differences in 18:1 and 18:1trans-11 concentrations due to dietary treatment, 18:1cis-11 concentrations were greater ($P = 0.001$) for CON and CON+VO steers when compared with 50DDGS and CON+CPVO fed steers. In addition, CON fed steers had greater 18:1cis-11 concentrations than either elevated CP steers ($P=0.002$) or steers on elevated fat diets ($P = 0.003$). Linoleic (18:2; $P = 0.39$), 18:3 ($P =0.33$), CLAcis- 9, trans-11 ($P = 0.42$) and CLAtrans-10, cis-12 ($P = 0.29$) concentrations were not different due to dietary treatment. Additionally, there were no differences in concentrations of 20:0 ($P = 0.44$) or 20:4 ($P = 0.78$) acids due to dietary treatment. Steers fed CON, CON+CP and CON+VO diets had greater ($P = 0.04$) ratios of MUFA:SFA when compared with CON+CPVO, while 50DDGS fed steers were intermediate to all treatments.

The depression in 16:1, in concert with the accumulation of 18:0 in cattle fed the CON+CPVO and 50DDGS diets, provides strong evidence that stearoyl-CoA desaturase (SCD) enzyme activity was depressed by these diets. This generally is an indication of depressed adipocyte differentiation, and these treatment groups had the lowest AFT and marbling scores. We have demonstrated previously that diets enriched with linoleic acid depress SCD activity and



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gene expression, and this phenomenon also has been demonstrated in rats and mice. We conclude that increasing levels of DDGS above 25% in the diet of finishing steers will depress fat development, most likely due to their elevated fat content.

## Implications

Data from this study suggest that performance and marbling are decreased when DDGS levels are increased from 25 to 50% of the diet (DM basis). This response appears to be related to the increased levels of both CP (N) and fat in the diet. However, diets containing 50% DDGS do not appear to have a negative effect on meat quality characteristics such as tenderness and case-life when compared with diets containing 25% DDGS.



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Table 1. Finishing diet ingredients and chemical composition

| | Treatments | | | | |
|---|---|---|---|---|---|
| Ingredient, % of diet DM | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO |
| Dry-rolled Corn | 60.7 | 35.7 | 49.2 | 57.1 | 45.8 |
| Dried distillers grains[1] | 24.8 | 49.8 | 25.1 | 25.1 | 25.5 |
| Corn silage | 12.2 | 12.2 | 11.9 | 13.2 | 12.1 |
| Corn gluten meal | --- | --- | 11.5 | --- | 11.4 |
| Soybean oil | --- | --- | --- | 2.4 | 2.8 |
| | | | | | |
| Supplement[2] | 2.3 | 2.2 | 2.3 | 2.2 | 2.3 |
| Limestone | 1.9 | 1.8 | 1.9 | 1.8 | 1.9 |
| Sodium Chloride | 0.22 | 0.21 | 0.22 | 0.21 | 0.22 |
| Akey beef premix No. 4[3] | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| Thiamine-10 premix[4] | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| | | | | | |
| Nutrient composition[5] | | | | | |
| Crude Protein | 15.36 | 21.29 | 22.10 | 15.45 | 21.93 |
| Ether Extract | 6.57 | 9.24 | 6.57 | 9.23 | 9.26 |
| NDF | 21.41 | 25.02 | 20.71 | 20.62 | 20.46 |
| ADF | 10.01 | 15.10 | 10.05 | 10.00 | 10.19 |
| Ash | 4.28 | 5.12 | 5.71 | 4.38 | 5.76 |
| Dry Matter | 79.13 | 79.11 | 79.59 | 78.24 | 79.86 |

[1]Dried distiller's grains contained (DM basis): 29.5% CP, 13.9% Fat, 14.3% ADF, 0.85% P, 0.04% Ca, 1.03% K, 0.27% Mg, 0.71% S, 0.26% Na, and 0.54 NEg.
[2]Provided NRC (2000) recommended levels of salt, trace minerals, and vitamins A, D, & E.
[3]Akey beef premix No. 4 (Akey, Inc., Lewisburg, OH) contained: 9% Mg, 4% S, 0.02% Co, 1% Cu, 0.09% I, 2% Fe, 4% Mn, 0.03% Se, 4% Zn as well as 4,400,000 IU of vitamin A, 550,000 IU of vitamin D and 5500 IU of vitamin E/kg of premix
[4]Diet formulated to contain 15 mg/kg of thiamine (22g of thiamine/kg of premix)
[5]Based on values obtained from complete mixed feed samples in our laboratory.

Table 2. Effects of differing levels of crude protein and fat from distiller's dried grains with solubles on performance in finishing steers

| | Treatment | | | | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO | SEM[2] | Treatment | CP | Fat |
| Days on feed | 95.1 | 95.5 | 96.6 | 98.2 | 91.3 | 3.55 | 0.71 | 0.91 | 0.96 |
| Initial BW, kg | 443.6 | 443.5 | 442.8 | 441.7 | 443.1 | 2.99 | 0.99 | 0.96 | 0.98 |
| Final BW, kg | 595.4$^{a}$ | 581.7$^{ab}$ | 583.0$^{ab}$ | 593.7$^{a}$ | 567.9$^{b}$ | 7.13 | 0.05 | 0.04 | 0.11 |
| DMI, kg/d | 10.15 | 9.88 | 9.75 | 9.83 | 9.60 | 0.22 | 0.39 | 0.14 | 0.16 |
| ADG, kg | 1.622$^{a}$ | 1.433$^{bc}$ | 1.482$^{abc}$ | 1.571$^{ab}$ | 1.386$^{c}$ | 0.063 | 0.04 | 0.01 | 0.03 |
| Gain/feed, kg/kg | 0.160 | 0.146 | 0.152 | 0.159 | 0.145 | <0.01 | 0.11 | 0.04 | 0.08 |

[1]Probabilites for overall treatment *F*-test and for pre-planned orthogonal contrasts between CON vs. elevated CP diets and CON vs. elevated fat diets.
[2]The greatest SEM was presented (n = 15 for CON, 50DDGS, CON+CP, and CON+CPVO; n = 14 for CON+VO).
[a,b,c]Means within a row lacking a common superscript differ ($P \leq 0.05$).



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Table 3. Effects of differing levels of crude protein and fat from distiller's dried grains with solubles on carcass characteristics in finishing steers

| | Treatment | | | | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO | SEM[2] | Treatment | CP | Fat |
| Hot carcass weight, kg | 369.1 | 360.3 | 362.3 | 368.7 | 349.7 | 6.5 | 0.08 | 0.07 | 0.15 |
| Dressing percent | 62.00 | 62.33 | 62.12 | 62.10 | 61.66 | 0.37 | 0.77 | 0.93 | 0.95 |
| Fat thickness, cm | 1.33 | 1.23 | 1.40 | 1.16 | 1.20 | 0.07 | 0.12 | 0.49 | 0.09 |
| LM area , $cm^2$ | 81.3 | 80.7 | 81.5 | 81.4 | 81.3 | 1.15 | 0.99 | 0.93 | 0.98 |
| KPH, % | 2.21 | 2.21 | 2.19 | 2.12 | 2.21 | 0.07 | 0.87 | 0.91 | 0.70 |
| Yield grade | 3.33 | 3.18 | 3.31 | 3.11 | 3.02 | 0.11 | 0.16 | 0.20 | 0.06 |
| Marbling score[2] | $612.9^{a}$ | $568.1^{ab}$ | $578.6^{ab}$ | $576.9^{ab}$ | $517.1^{b}$ | 22.8 | 0.05 | 0.03 | 0.03 |
| Quality grade[3] | $17.67^{a}$ | $17.29^{ab}$ | $17.29^{ab}$ | $17.30^{ab}$ | $16.71^{b}$ | 0.22 | 0.03 | 0.02 | 0.02 |
| USDA Choice or Prime, % | 90.5 | 85.7 | 90.5 | 85.0 | 66.7 | 8.2 | 0.25 | 0.31 | 0.22 |

[1]Probabilites for overall treatment *F*-test and for pre-planned orthogonal contrasts between CON vs. elevated CP diets and CON vs. elevated fat diets.
[2]The greatest SEM was presented (n = 15 for CON, 50DDGS, CON+CP, and CON+CPVO; n = 14 for CON+VO).
[3]Marbling score: 400 = Slight 0, 450 = Slight 50, 500 = Small 0, etc.
[4]Quality grade: 15 = $Select^{-}$, 16 = $Select^{+}$, 17 = $Choice^{-}$, 18 =$Choice^{0}$, 19 = $Choice^{+}$, etc.
[a,b,c]Means within a row lacking a common superscript differ ($P \leq 0.05$).

Table 4. Main effect of treatment of differing levels of crude protein and fat from distiller's dried grains with solubles on circulating plasma metabolite and hormone concentrations in finishing steers

| | Treatment | | | | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO | SEM[2] | Treatment | CP | Fat |
| Glucose, mg/dL | 41.09 | 41.78 | 39.06 | 40.45 | 40.59 | 1.59 | 0.73 | 0.90 | 0.66 |
| Insulin, µIU/mL | 9.03 | 8.57 | 10.44 | 12.52 | 9.51 | 1.97 | 0.50 | 0.77 | 0.43 |
| Urea nitrogen, mg/dL | $9.92^{c}$ | $12.96^{b}$ | $14.04^{ab}$ | $11.22^{c}$ | $14.57^{a}$ | 0.57 | <0.0001 | <0.0001 | <0.0001 |

[1]Probabilites for overall treatment and main effects *F*-test and for pre-planned orthogonal contrasts between CON vs. elevated CP diets and CON vs. elevated fat diets.
[2]Glucose and insulin: n = 9 for all treatments on d 63; Urea nitrogen: n = 15 for all treatments on d 63.
[a,b,c]Means within a row lacking a common superscript differ ($P \leq 0.05$).

Table 5. Main effects of day and time of sampling on circulating plasma metabolite and hormone concentrations in finishing steers

| | Day | | | | | Time of Sampling | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | 63 | 91 | 119 | SEM[1] | *P*-value | Preprandial | 2 h | 4 h | 6 h | SEM[2] | *P*-value |
| Glucose, mg/dL | $45.49^{a}$ | $39.58^{b}$ | $36.72^{b}$ | 1.54 | <0.0001 | $43.19^{a}$ | $38.24^{b}$ | $39.25^{b}$ | $41.71^{a}$ | 0.97 | <0.0001 |
| Insulin, µIU/mL | 10.34 | 10.10 | 9.61 | 1.92 | 0.95 | $13.04^{a}$ | $10.71^{ab}$ | $8.48^{bc}$ | $7.84^{c}$ | 1.21 | 0.0005 |
| Urea nitrogen, mg/dL | $15.25^{a}$ | $12.11^{b}$ | $10.27^{c}$ | 0.54 | <0.0001 | -- | -- | -- | -- | -- | -- |

[1]The greatest SEM was presented (Glucose and insulin: n = 45 on d 63, n = 31 on d 91, and n = 15 on d 119; Urea nitrogen: n = 105 on d 63, n = 70 on d 91 and n = 31 on d 119).
[2]n = 91
[a,b,c]Means within a row lacking a common superscript differ ($P \leq 0.05$).



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Table 6. Effects of differing levels of crude protein and fat from distiller's dried grains with solubles on Warner-Bratzler shear force and crude fat percentage of *longissimus dorsi* samples from finished steers

| | Treatment | | | | | | |
|---|---|---|---|---|---|---|---|
| Item | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO | SEM[1] | *P*-value |
| WBS, kg | 4.92 | 4.86 | 4.42 | 5.59 | 4.49 | 0.39 | 0.18 |
| Ether Extract, % crude fat | 5.59 | 6.10 | 7.07 | 5.88 | 4.82 | 0.80 | 0.34 |

[1]The greatest SEM was presented (n = 9 for 50DDGS, CON+CP, CON+VO and CON+CPVO; n = 8 for CON).

Table 7. Fatty acid composition of subcutaneous adipose tissue on steers fed differing levels of crude protein and fat from distiller's dried grains with solubles (three replications per treatment)

| | Treatment | | | | | | *P*-value[1] | | |
|---|---|---|---|---|---|---|---|---|---|
| Fatty acid | CON | 50DDGS | CON+CP | CON+VO | CON+CPVO | SEM[2] | Treatment | CP | Fat |
| | g/100 g of identified fatty acids[3] | | | | | | | | |
| 14:0 | 3.00 | 2.98 | 3.19 | 3.01 | 3.49 | 0.21 | 0.39 | 0.35 | 0.50 |
| 14:1 | 1.09 | 1.00 | 1.20 | 1.09 | 1.06 | 0.10 | 0.65 | 0.99 | 0.74 |
| 16:0 | 25.75 | 25.42 | 25.69 | 23.89 | 26.49 | 0.80 | 0.21 | 0.89 | 0.58 |
| 16:1 | 3.47[a] | 3.03[ab] | 3.53[a] | 3.37[a] | 2.75[b] | 0.21 | 0.04 | 0.11 | 0.07 |
| 18:0 | 12.30[bc] | 13.64[ab] | 11.73[c] | 12.10[bc] | 14.15[a] | 0.64 | 0.04 | 0.22 | 0.16 |
| 18:1*trans*-11 | 1.64 | 2.36 | 1.64 | 2.56 | 2.64 | 0.44 | 0.14 | 0.19 | 0.05 |
| 18:1 | 41.55 | 41.08 | 40.69 | 39.74 | 39.32 | 1.05 | 0.51 | 0.31 | 0.20 |
| 18:1*cis*-11 | 1.41[a] | 1.12[bc] | 1.29[ab] | 1.32[a] | 0.99[c] | 0.07 | 0.001 | 0.002 | 0.003 |
| 18:2 | 2.42 | 3.13 | 2.91 | 2.80 | 3.12 | 0.37 | 0.39 | 0.07 | 0.09 |
| 18:3 | 0.03 | 0.03 | 0.04 | 0.08 | 0.10 | 0.03 | 0.33 | 0.42 | 0.23 |
| CLA*cis*-9, *trans*-11 | 0.33 | 0.36 | 0.39 | 0.26 | 0.28 | 0.06 | 0.42 | 0.82 | 0.63 |
| CLA*trans*-10, *cis*-12 | 0.12 | 0.03 | 0.10 | 0.09 | 0.01 | 0.05 | 0.29 | 0.12 | 0.11 |
| 20:0 | 0.22 | nd[d] | nd[d] | nd[d] | nd[d] | 0.11 | 0.44 | 0.06 | 0.06 |
| 20:4 | 1.64 | 1.20 | 1.62 | 1.58 | 0.58 | 0.70 | 0.78 | 0.51 | 0.50 |
| MUFA:SFA | 1.17[a] | 1.08[ab] | 1.16[a] | 1.16[a] | 0.96[b] | 0.05 | 0.04 | 0.11 | 0.11 |

[1]Probabilites for overall treatment *F*-test and for pre-planned orthogonal contrasts between CON vs. elevated CP diets and CON vs. elevated fat diets.
[2]The greatest SEM was presented (n = 9 for CON, 50DDGS, CON+CP, and CON+VO; n = 8 for CON+CPVO).
[3]Calues are g/100g of identified fatty acids.
[a,b,c]Means within a row lacking a common superscript differ ($P \leq 0.05$).
[d]nd = not detected



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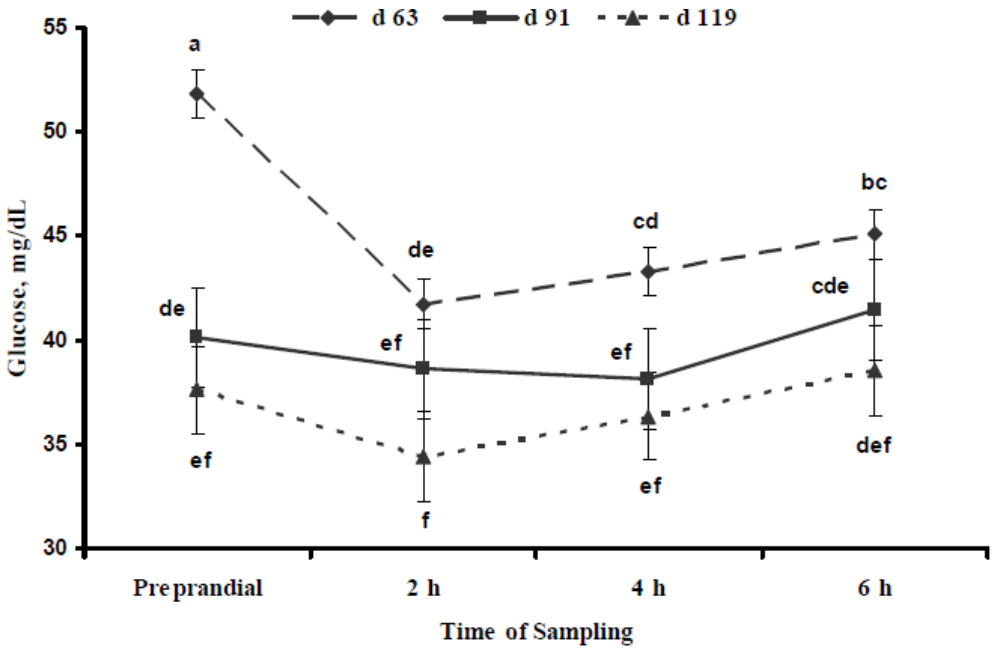


**Figure 1.** Day of sampling × time of sampling interaction ($P = 0.001$) for circulating plasma concentration of glucose in finishing steers. Samples were taken in 28 d intervals preprandially, 2 h postprandially (2 h), 4 h postprandially (4 h), and at 6 h postprandially (6 h). [a-f]Data points lacking a common superscript are different ($P < 0.05$).

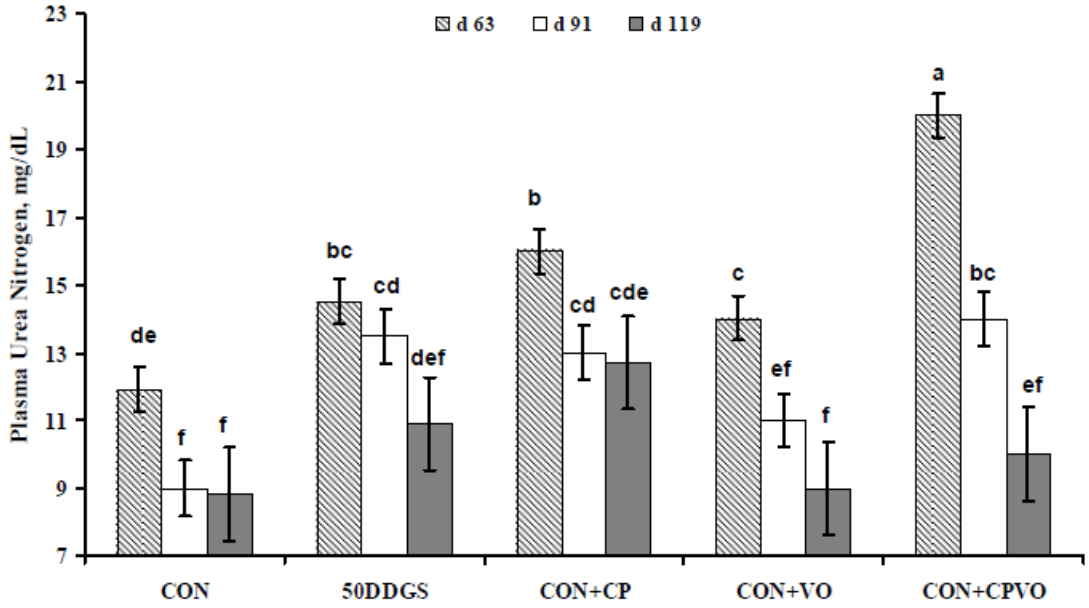


**Figure 2.** Treatment × day of sampling interaction ($P = 0.008$) for circulating plasma urea nitrogen concentration in finishing beef steers. Samples were taken in 28 d intervals preprandially. [a-f]Data points lacking a common superscript are different ($P < 0.05$).



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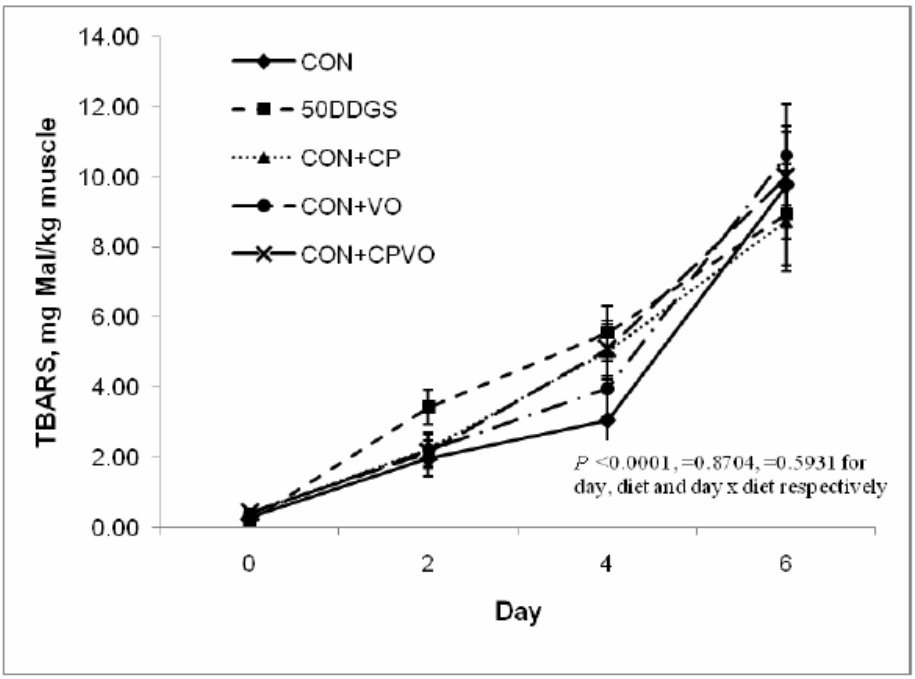


**Figure 3**. Effect of differing levels of crude protein and fat from distiller's dried grains with soluble on TBARS values of ground beef samples from finished steers. Points represent means ± SE.

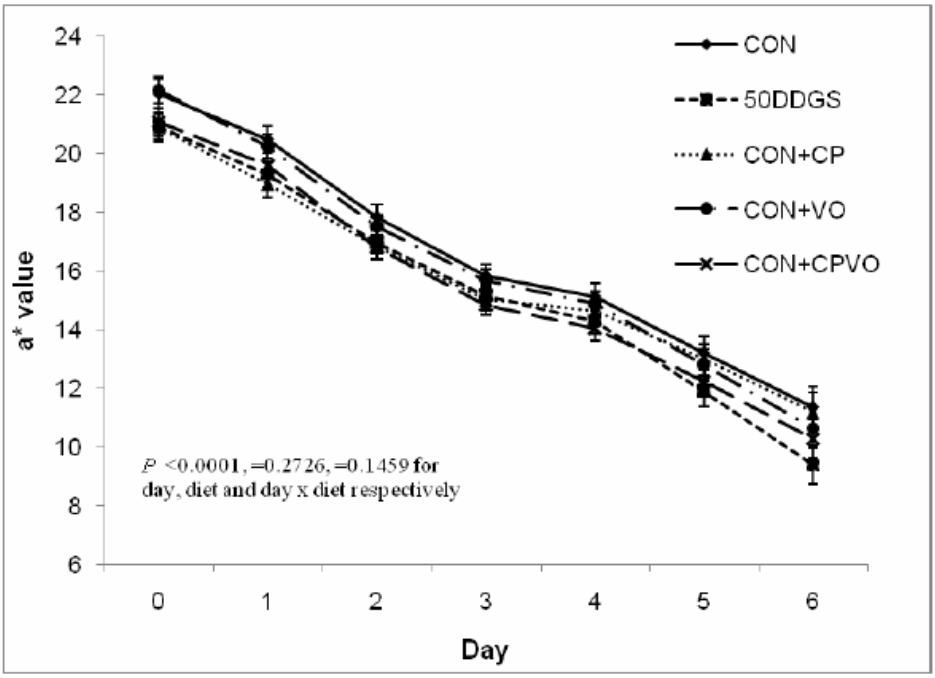


**Figure 4**. Effect of differing levels of crude protein and fat from distiller's dried grains with soluble on a* values of ground beef samples from finished steers. Points represent means ± SE.



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