Effects of Low-, Medium-, and High-Oil Dried Distillers Grains with Solubles on Growth Performance, Nutrient Digestibility, and Fat Quality in Finishing Pigs[1]

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Summary

A total of 1,480 pigs were used in 3 experiments to determine the effects of dried distillers grains with solubles (DDGS) varying in oil content on growth performance, carcass characteristics, carcass fat quality, and nutrient digestibility in growing-finishing pigs. In Exp. 1, 1,198 pigs (PIC 337 × 1050, initially 101.6 lb) were used to evaluate the effects of corn DDGS with 5.4 or 9.6% oil (as-fed). Pigs were allotted to a corn-soybean meal–based control diet or diets with 20 or 40% of the two DDGS sources. From d 0 to 82, ADG was unaffected by DDGS source or level. Increasing 5.4% oil DDGS made F/G poorer (linear, $P < 0.01$), whereas F/G did not change for pigs fed 9.6% oil DDGS. Regardless of DDGS source, carcass yield and HCW decreased (linear, $P < 0.04$) with increasing DDGS. Increasing DDGS increased jowl iodine value (IV), but the magnitude was greater in pigs fed the 9.6% oil DDGS compared with those fed 5.4% oil DDGS (DDGS source × level interaction; $P < 0.01$). In Exp. 2, a total of 270 pigs (PIC 327 × 1050, initially 102.5 lb) were allotted a corn-soybean meal–based control diet with 20 or 40% of a 9.4% oil or 12.1% oil DDGS. From d 0 to 75, ADG increased for pigs fed increasing 9.4% oil DDGS but not for pigs fed 12.1% oil DDGS (quadratic interaction, $P < 0.02$). Increasing DDGS increased (linear, $P < 0.01$) jowl IV and tended (linear, $P < 0.07$) to improve F/G. Regardless of source, HCW and carcass yield decreased (linear, $P < 0.05$) as DDGS increased. In Exp. 3, nutrient digestibility of the 4 DDGS sources was determined using pigs fed either a corn-based basal diet or a DDGS diet with 50% basal diet and 50% DDGS. On an as-fed basis, corn contained 1,756 and 1,594 kcal/lb GE and DE, respectively. The 5.4, 9.6, 9.4, and 12.1% oil DDGS contained 1,972, 2,108, 2,142, and 2,224 kcal/lb (as-fed) GE and 1,550, 1,674, 1,741, and 1,694 kcal/lb DE, respectively (as-fed). Stepwise regression indicated that the oil (ether extract) content was the only significant variable in explaining differences in energy content, and that a 1% change in oil content will change the DE by 28 kcal/lb (Adjusted $R^2 = 0.41$) and NE by 52 kcal/lb (Adjusted $R^2 = 0.86$; as-fed).

Key words: corn, DDGS, digestibility, growth performance, finishing pigs, iodine value

Introduction

Dried distillers grains with solubles are a by-product of the ethanol industry and are commonly used to replace portions of corn and soybean meal in swine diets. Tradi-

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tional DDGS with approximately 10% oil have a relatively similar feeding value to that of corn. In a review of over 20 papers, Stein and Shurson (2009[3]) concluded that growth performance will remain unchanged when feeding DDGS up to 30% of the diet; however, carcass characteristics such as carcass yield and jowl IV are adversely affected by feeding DDGS because of its high unsaturated fatty acid content.

As the value of corn oil has risen, ethanol plants have begun implementing oil extraction procedures to remove a greater portion of the corn oil, resulting in DDGS that vary in oil content from approximately 4 to 12%. Because the feeding value of DDGS is largely based on its energy content, changing the oil content of DDGS may affect growth performance. As a result, NRC (2012[4]) values for DDGS are based on oil content and are categorized as low (>4% oil), medium (between 6 and 9% oil), or high-oil (>10%).

Research suggests that variables such as GE, ash, oil (ether extract), ADF, and total dietary fiber are significant in estimating energy values of corn co-products (Pederson et al., 2007[5]; Anderson et al., 2011[6]); however, relatively few studies are available comparing the feeding value of DDGS containing less than 8% ether extract. Therefore, the objectives of this study were to evaluate the effects of DDGS with varied oil contents on finishing pig growth performance, carcass characteristics, and carcass fat quality and to determine the DE content and nutrient digestibility relationships between DDGS sources.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments.

Experiment 1 was conducted in a commercial research-finishing barn in southwestern Minnesota. The barn was naturally ventilated and double-curtain-sided. Pens had completely slatted flooring and deep pits for manure storage. Each pen (18 ×10 ft) was equipped with a 5-hole stainless steel dry self-feeder (Thorp Equipment, Thorp, WI) and a cup waterer for ad libitum access to feed and water.

Experiment 2 was conducted at the K-State Swine Teaching and Research Center in Manhattan, KS. The facility was a totally enclosed, environmentally regulated, mechanically ventilated barn containing 36 pens (8 × 10 ft). The pens had adjustable gates facing the alleyway, allowing for 10 ft^2/pig. Each pen was equipped with a cup waterer and a single-sided, dry self-feeder (Farmweld, Teutopolis, IL) with 2 eating spaces located in the fence line. Pens were located over a completely slatted concrete floor with a 4-ft pit underneath for manure storage. Facilities in both Exp. 1 and 2 were equipped with a computerized feeding system (FeedPro; Feedlogic Corp., Willmar, MN) that delivered

[3] Stein, H.H., and G.C. Shurson. 2009. Board-Invited Review: The use and application of distillers dried grains with solubles (DDGS) in swine diets. J. Anim. Sci. 87:1292–1303.
[4] NRC. 2012. Nutrient Requirements of Swine. 11th rev. ed. Natl. Acad. Press, Washington, DC.
[5] Pederson, C., M.G. Boersma, and H.H. Stein. 2007. Digestibility of energy and phosphorus in ten samples of distillers dried grains with solubles fed to growing pigs. J. Anim. Sci. 85:1168–1176.
[6] Anderson, P.V., B.J. Kerr, T.E. Weber, C.J. Ziemer, and G.C. Shurson. 2012. Determination and prediction of digestible and metabolizable energy from chemical analysis of corn coproducts fed to finishing pigs. J. Anim. Sci. 90:1242–1254.

and recorded daily feed additions and diets as specified. The equipment provided pigs with ad libitum access to food and water.

In Exp. 3, pigs were housed in a totally enclosed, environmentally controlled, mechanically ventilated facility containing 12 stainless steel metabolism cages (5 × 2 ft). Each cage was equipped with a feeder as well as a nipple waterer to allow ad libitum access to water and had metal mesh flooring that allowed for total collection of feces.

Animals and diets

Samples of DDGS from Exp. 1 were taken upon delivery of every new batch, whereas DDGS from Exp. 2 were from a single batch of either 9.4 or 12.1% oil DDGS. Corn samples were obtained at the time of diet manufacture for Exp. 3. These DDGS and corn samples were combined and homogenized, and subsamples were taken and analyzed for DM, CP, crude fiber, NDF, ADF, and ether extract at a commercial laboratory (Ward Laboratories, Inc., Kearney, NE; Table 1). Amino acid profile was analyzed at the University of Missouri-Columbia Agricultural Experiment Station Chemical Laboratory (Columbia, MO; AOAC, 2006; Table 1). Fatty acid analysis (Sukhija and Palmquist, 1988) was conducted at the K-State Analytical Lab (Manhattan, KS; Table 2). Samples of ingredients were taken from every DDGS delivery, and a composite sample was used to measure bulk density (Table 3). Bulk density of a material represents the mass per unit of volume (lb/bu). Lastly, particle size was measured on all DDGS sources used.

Experiment 1

A total of 1,198 pigs (PIC 337 × 1050, Hendersonville, TN; initially 101.6 lb BW) were used in an 82-d growth study to determine the effects of 5.4 or 9.6% oil corn DDGS in finishing diets on growth performance, carcass characteristics, and carcass fat quality. Pens with 26 or 27 pigs per pen were randomly allotted to 1 of 5 treatment groups, with average pig BW balanced across treatments to provide 9 replications per treatment. All diets were fed in meal form, with treatments delivered over 3 phases (101 to 157, 157 to 231, and 231 to 284 lb; Tables 4, 5, and 6). Pigs were allotted to a corn-soybean meal–based control diet with 20 or 40% of the 5.4% oil DDGS or 9.6% oil DDGS. Diets were balanced across treatments by phase for standardized ileal digestible (SID) lysine and available P but not for energy. At the time of diet formulation, the 2012 NRC publication was not available; therefore, total amino acid and SID coefficients in DDGS from Stein (2007[7]) were used in diet formulation.

On d 61, the 3 heaviest pigs from each pen (determined visually) were weighed and sold in accordance with the farm's normal marketing procedure. Near the conclusion of the trial, all remaining pigs were tattooed according to pen number and dietary treatment to allow for carcass data collection and data retrieval by pen. On d 82, 2 medium-weight barrows were selected from each pen and transported approximately 1.5 h to a commercial packing plant (Sioux-Preme Packing Co., Sioux Center, IA), where they were harvested, and jowl, backfat, and belly fat samples were collected and analyzed for their fatty acid content. Jowl samples were collected from the distal end of the carcass, and belly fat samples were taken along the midline, parallel to the diaphragm.

[7] Stein, H.H. 2007. Feeding distillers dried grains with solubles (DDGS) to swine. Swine Focus #001. University of Illinois Extension, Urbana-Champaign, IL.

Backfat samples were taken midline at the 10th rib, with care taken to sample all 3 layers. Fatty acid analysis was conducted in the University of Nebraska Department of Nutrition and Health Sciences Analytical Lab. On d 82, the remaining pigs were transported approximately 1 h to a different commercial packing plant (JBS Swift and Company, Worthington, MN) for data collection. Standard carcass criteria of percentage carcass yield, HCW, backfat depth, loin depth, and percentage lean were calculated. Hot carcass weight was measured immediately after evisceration, and carcass yield was calculated as HCW divided by live weight at the plant. Fat depth and loin depth were measured with an optical probe inserted between the third- and fourth-last rib (counting from the ham end of the carcass) at a distance approximately 3 in. from the dorsal midline. Fat-free lean index (FFLI) was calculated according to National Pork Producers Council (1991[8]) procedures.

Experiment 2

A total of 270 pigs (PIC 327 × 1050, Hendersonville, TN; initially 102.5 lb BW) were used in a 75-d growth study to determine the effects of 9.4 or 12.1% oil corn DDGS in finishing diets on pig growth performance and carcass characteristics. There were 8 pigs per pen and 7 replications per treatment. All diets were fed in meal form, and treatments were fed over 3 phases (103 to 161, 161 to 220, and 220 to 269 lb; Tables 4, 5, and 6). Pigs were allotted to a corn-soybean meal–based control diet or diets with 20 or 40% of 9.4%-oil DDGS or 12.1%-oil DDGS. In this study, NRC (2012) nutrient values for DDGS with greater than 10% oil were used to formulate both DDGS sources. Diets were formulated above the pigs' estimated requirements for amino acids to avoid limiting growth performance. All pigs and feeders were weighed on d 0, 14, 26, 38, 54, and 75 to determine ADG, ADFI, and F/G.

On d 75, all pigs were weighed and transported approximately 2.5 h to a commercial packing plant (Triumph Foods LLC, St. Joseph, MO) for harvest under USDA inspection. Before slaughter, pigs were individually tattooed according to pen number to allow for carcass data collection at the packing plant and data retrieval by pen. Hot carcass weight was measured immediately after evisceration, and each carcass was evaluated for carcass yield, backfat depth, loin depth, percentage lean, and jowl IV. Carcass yield was calculated by dividing HCW at the plant by live weight at the farm before transport to the plant. Fat depth and loin depth were measured with an optical probe inserted between the third- and fourth-last rib. Jowl fat samples were collected and analyzed by near-infrared spectroscopy (Bruker MPA, Breman, Germany) at the plant for IV using the equation of Cocciardi et al. (2009[9]).

Experiment 3

A total of 12 barrows (PIC 327 × 1050, Hendersonville, TN; initially 56.4 lb BW) were used in a 6-wk study to determine nutrient digestibility of corn and the 4 DDGS sources used in Experiments 1 and 2 as well as a fifth source of medium-oil DDGS used

[8] NPPC. 1991. Procedures to evaluate market hogs. 3rd ed. National Pork Producers Council, Des Moines, IA.

[9] Cocciardi, R.A., J.M. Benz, H. Li, S.S. Dritz, J.M. DeRouchey, M.D. Tokach, J.L. Nelssen, R.D. Goodband, and A.W. Duttlinger. 2009. Analysis of iodine value in pork fat by Fourier transform near infrared spectroscopy for pork fat quality assessment. J. Anim. Sci. 87(Suppl. 2):579. (Abstr.).

in a different growth study outlined by Graham (2013[10]). The fifth source contained 7.6% oil, 30.1% CP, 19.53% ADF, and 36.47% NDF (as-fed). The 5 DDGS sources plus the control corn-basal diets were evaluated using a replicated Latin square design with 6 pigs assigned to each square to achieve 12 replications per diet. The pigs within each replicate square were randomly allotted to treatment within each period using the PLAN procedure of SAS (SAS Inst. Inc., Cary, NC). The sources of DDGS used in the digestibility study were from the same batches as the corresponding growth trials. Nutrient digestibility of the DDGS source was determined by feeding either a 96.6% corn-based basal diet (96.6% corn, 3.4% vitamins and minerals) or 50% basal diet and 50% DDGS (Table 6); thus, vitamins and minerals in the test diet were fed at half of the levels fed in the corn-basal diet.

Pigs were fed the same amount of each diet for the duration of each 7-d period. Feeding level was 2.5 times maintenance requirements and was determined based on pig BW on d 1 of each period. Daily rations were equally divided between two meals fed at 0600 and 1800 h. Each period consisted of 5 d of diet adjustment (10 meals) followed by 2 consecutive days of total fecal collection. On the morning of day 6 (meal 11), pigs were allowed approximately 5 min to stand, drink, and defecate before eating. After that time, feces were removed and the morning meal was fed. This meal on the morning of d 6 marked the beginning of the timed fecal collection period. On d 8 of period 1, (d 1 of period 2 or meal 15), the same amount of time was given to pigs, allowing them to stand up, drink, and defecate. Before feeding, all feces were collected, marking the end of the timed collection period. On the same morning that collection ended, pigs were weighed and fed a new treatment diet in a random order. Feces were stored in a freezer until further processing and analysis. At the conclusion of a collection period, all feces for each pig were combined, homogenized, and dried in a forced-air oven. Samples were finely ground, then subsampled for further analysis following the procedures of Jacela et al. (2010[11]). Gross energy concentrations of the ingredients, diets, and fecal samples were measured via adiabatic bomb calorimetry. Calculations outlined by Adeola (2001[12]) were used to determine energy values. Ingredients, diets, and feces were also analyzed for DM, CP, crude fiber, NDF, ADF, and ether extract at a commercial laboratory (Ward Laboratories, Inc., Kearney, NE).

Statistical analysis

Data for the growth trials were analyzed as a completely randomized design with pen as the experimental unit and treatment as a fixed effect; IV analysis in Exp. 1, however, was analyzed using a completely randomized design with the fixed effect of treatment and the random effect of pen. Analysis of variance was used with the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Because HCW differed, it was used as a covariate for backfat, loin depth, and percentage lean. For Exp. 1 and 2, contrasts were used to make comparisons between (1) the linear and quadratic interactions of DDGS

[10] Graham, A.B. 2013. The effects of low-, medium-, and high-oil dried distillers grains with solubles (DDGS) on growth performance, nutrient digestibility, and fat quality in finishing pigs. MS Thesis. Kansas State Univ., Manhattan.
[11] Jacela, J.Y., J.M. Benz, S.S. Dritz, M.D. Tokach, J.M. DeRouchey, R.D. Goodband, J.L. Nelssen, and K.J. Prusa. 2010. Effect of dried distillers grains with solubles (DDGS) withdrawal regimens on finishing pig performance and carcass traits. J. Anim. Sci. 88 (Suppl. 3):53 (Abstr.).
[12] Adeola, O. 2001. Digestion and balance techniques in pigs. In: A.J. Lewis and L.L. Southern, Editors, Swine Nutrition. 2nd ed. CRC Press, New York, NY. p. 903–916.

source × level; (2) corn-soy and 20% and 40% DDGS-containing diets; and (3) linear and quadratic effects of increasing DDGS. In Exp. 3, period, pig, and Latin square were random effects and treatment was a fixed effect. Single degree of freedom contrasts were used to separate means of pigs fed either the corn- or DDGS-based diet in the nutrient balance study. Differences were considered significant at $P \leq 0.05$ and a trend at $P > 0.05$ and $P \leq 0.10$. Stepwise regression was used to determine the effect of the feedstuff composition on DE and NE. Variables were retained in the model with P-values ≤ 0.15. The adjusted R^2, the SE of the estimate, the SE, and the Mallows statistic [C(p)] were used to define the best-fit equation. If the intercept was determined insignificant in the final prediction model, it was excluded from the model and an adjusted R^2 value was calculated using the NOINT option of SAS.

Results

Chemical analysis

Analyzed samples of DDGS were similar in CP concentrations but considerably varied in fiber content (Table 1). Crude fiber ranged from 7.9 to 12% on an as-fed basis, with crude fiber increasing as oil content increased. The same overall trend was observed in ADF and NDF concentrations.

According to NRC (2012), the lysine concentrations in low, medium-, and high-oil DDGS are 0.68, 0.90, and 0.77%, respectively. The analysis of AA on the 5.4, 9.6, 9.4, and 12.1%-oil DDGS showed that lysine concentrations were 1.03, 1.12, 1.00, and 0.90%, respectively (Table 1). The analyzed values of lysine from the DDGS sources were greater than those used in diet formulation, so diets containing DDGS contained slightly more lysine and other amino acids than calculated; therefore, lysine should not have limited pig performance. The remaining analyzed amino acids were similar in concentration to values listed in the NRC (2012). Fatty acid analyses was similar among the DDGS samples (Table 2).

Bulk density tests on the ingredients used in this study further demonstrated the variability in DDGS from different ethanol plants (Table 3). Research has established that as DDGS are added to corn-soybean meal–based diets, diet bulk density decreases (Asmus, 2012[13]). Ethanol plants have begun to implement extra centrifugation processes to capture more corn oil during ethanol production (CEPA, 2011[14]). Although we would expect oil removal to reduce bulk density, bulk density did not appear to be greatly influenced by oil content. Particle size varied from 371 to 744 microns in the DDGS used in these experiments.

Experiment 1

Overall (d 0 to 82), ADG was unaffected by DDGS source or level, although a DDGS source × level interaction ($P < 0.02$) was observed for ADFI and F/G. Increasing 5.4%-oil DDGS increased ADFI and worsened F/G, but no significant change occurred in

[13] Asmus, M.D. 2012. Effects of dietary fiber on the growth performance, carcass characteristics, and carcass fat quality in growing-finishing pigs. MS. Thesis. Kansas State Univ., Manhattan.
[14] California Environmental Protection Agency. 2011. California-Modified GREET Pathway for the Production of Biodiesel from Corn Oil at Dry Mill Ethanol Plants. Stationary Source Division, Release Date: November, 3, 2011, Version 2.0. 40 pp.

ADFI or F/G when pigs were fed increasing amounts of 9.6%-oil DDGS (Table 7). No significant differences in final BW were observed.

Regardless of DDGS source, carcass yield and HCW decreased (linear, $P < 0.04$) with increasing DDGS (Table 8). As DDGS increased, loin depth tended to increase (quadratic, $P = 0.05$), especially in pigs fed the 9.6%-oil DDGS source. DDGS source × level interactions (linear, $P < 0.02$) were observed for jowl, belly, and backfat IV. Increasing DDGS increased jowl, belly, and backfat IV, but the magnitude of increase was greater in pigs fed the 9.6%-oil DDGS than in those fed the 5.4%-oil DDGS.

Experiment 2

Overall (d 0 to 75), ADG increased in pigs fed 20% of the 9.4%-oil DDGS but decreased slightly in those fed 40% DDGS compared with control-fed pigs (quadratic interaction, $P < 0.02$; Table 9). Average daily gain did not differ among pigs fed 12.1%-oil DDGS. Increasing DDGS, regardless of source, tended (linear, $P < 0.06$) to improve F/G. As DDGS increased, ADFI decreased (linear, $P < 0.04$), regardless of source. Final BW followed the same trend as ADG (quadratic interaction, $P < 0.10$), with the pigs fed 40% DDGS (which contained 9.4% oil) having the lowest final BW among all treatments.

Regardless of source, increasing DDGS decreased (linear, P < 0.04) carcass yield and HCW (Table 10). No significant differences were observed in backfat depth, loin depth, or percentage lean. Increasing DDGS increased (linear, $P < 0.01$) jowl IV, but to a greater extent in pigs fed 12.1%-oil DDGS than those fed 9.4%-oil DDGS (DDGS source × level interaction, linear, $P < 0.001$) for jowl IV.

Experiment 3

Gross energy values observed for the corn, 5.4, 9.6, 9.4, and 12.1%-oil DDGS used in the growth portion of this study were 1,756, 1,972, 2,108, 2,142, and 2,224 kcal/lb, respectively (as-fed; Table 11). Based on the corresponding GE digestibility coefficients calculated for each DDGS source (Table 12), DE values for the corn, 5.4, 9.6, 9.4, and 12.1% oil DDGS were 1,594, 1,550, 1,674, 1,741, and 1,694 kcal/lb, respectively (as-fed). Dry matter digestibility was relatively similar among the 4 DDGS sources. Crude protein digestibility was highest in the 9.4 and 9.6%-oil DDGS. Digestibility of the ether extract in DDGS was considerably more variable, ranging from approximately 62 to 76%. In general, the digestibility of ether extract increases as the oil content of DDGS increased, with the exception of the 9.6%-oil DDGS used in this study. Acid detergent fiber digestibility of the DDGS sources increased as the oil content increased, with the exception of the 9.4%-oil DDGS source, which was intermediate. Neutral detergent fiber and CF digestibility did not follow this pattern and varied among sources.

Discussion

Research has shown that corn DDGS can be fed at up to 30% of the diet without adversely affecting growth performance because >10%-oil DDGS has an energy value similar to that of corn (Stein, 2007). As new oil extraction capabilities are implemented in ethanol plants to harvest more corn oil, reduced-oil DDGS are becoming more abundant in the marketplace. One concern is that the new, reduced-oil DDGS might negatively affect pig growth performance, as was the case in recent research by Graham (2013), where feeding pigs increasing medium-oil DDGS (7.6% oil) linearly decreased ADG and worsened F/G.

The hypothesis in the current study was that oil content would be highly significant in predicting energy values of DDGS sources varying considerably in oil content. Stepwise regression was used to determine DE and NE equations based on the 4 DDGS sources used in the growth portion of this study and one other source of DDGS outlined by Graham (2013). The DDGS source used in Graham (2013) contained 7.6% oil (as-fed basis) and had DE of 1,522 kcal/lb. The DE content of the corn and the 5 DDGS were determined using the digestibility data collected from the 12 pigs housed in metabolism crates. The GE and DE values observed for the corn used in this study, 1,756 and 1,594 kcal/lb (as-fed), respectively, were similar to published values (1,811 and 1,565 kcal/lb, respectively; NRC, 2012). The GE values observed for the 5.4, 9.6, 9.4, and 12.1%-oil DDGS used in the growth portion of this study were 1,972, 2,108, 2,142, and 2,224 kcal/lb, respectively (as-fed; Table 11). These compare to values listed in the NRC (2012) for low-, medium-, and high-oil DDGS of 2,312, 2,136, and 2,199 kcal/lb (as-fed), respectively. In contrast to GE values from NRC (2012), those observed in the current study increased as oil content in DDGS increased.

Gross energy digestibility coefficients determined in the current study for 5.4, 9.6, 9.4, and 12.1% oil DDGS were 78.6, 79.4, 81.3, and 76.1%, respectively. The calculated GE digestibility coefficients from low-, medium-, and high-oil DDGS in NRC (2012) are 64.6, 76.1, and 74.7%, respectively.

Based on the corresponding GE digestibility coefficients calculated for each DDGS source (Table 12), DE values for the 5.4, 9.6, 9.4, and 12.1%-oil DDGS were 1,550, 1,674, 1,741, and 1,694 kcal/lb, respectively (as-fed). These DE values compare to values listed in the NRC (2012) for low-, medium-, and high-oil DDGS of 1,493, 1,625, and 1,642 kcal/lb (as-fed), respectively. In the current study, similar to NRC (2012) values, DE increases as the oil content of DDGS sources increases, with the exception of the 12.1%-oil DDGS source, which is intermediate. The NE of the DDGS sources was calculated based on the actual growth performance from Exp. 1 and 2 and data from the 7.6% oil DDGS from Graham (2013). Net energy efficiency (NEE) was determined by calculating the calories of NE intake in kcal/per lb of gain on a phase basis (studies utilized either 2- or 3-phase feeding strategies), using solving functions to set the NEE of pigs fed each DDGS source equal to that of those fed the corn-soybean meal control diet. This was done with the assumption that the NE contents of corn and soybean meal were 1,212 and 947 kcal/lb, respectively (as-fed; NRC, 2012).

Based on results from the growth portion of the current study, as well as those of Graham (2013), energy content of DDGS sources should be considered in determining a price relative to corn because of reduced feeding values from the extraction of larger quantities of corn oil from DDGS. This conclusion agrees with previous research that determined the NE value of 7.8% oil DDGS is less than the stated value for DDGS with 6–9% oil in the NRC (2012), indicating a wide range of energy values that are dependent on the oil content of DDGS. The equations generated to predict DE and NE as a function of oil content on an as-fed basis were: DE (kcal/lb) = 28.28 × ether extract (%) + 1387 (n=5, Adjusted R^2 = 0.41); NE (kcal/lb) = 52.17 × ether extract

(%) + 681 (n=5, Adjusted R^2 = 0.86; Figure 1). These equations indicate that changing the oil content 1% in DDGS will change the DE by 28 kcal/lb and NE by 52 kcal/lb on an as-fed basis.

Table 1. Analyzed nutrient composition of ingredients (as-fed basis)[1]

		Exp. 1		Exp. 2	
Item, %	Corn	5.4% oil DDGS[2]	9.6% oil DDGS	9.4% oil DDGS	12.1% oil DDGS
DM	88.03	92.38	91.97	93.17	93.20
CP	8.80	29.53	29.63	29.40	28.53
Crude fiber	3.85	7.93	11.02	11.25	12.07
ADF	5.83	8.90	15.25	19.57	17.57
NDF	16.22	21.75	28.58	34.50	31.38
Ash	1.49	4.90	3.94	4.65	4.61
Amino acids					
Arginine	---	1.31	1.30	1.38	1.27
Cysteine	---	0.57	0.54	0.54	0.46
Histidine	---	0.79	0.77	0.78	0.69
Isoleucine	---	1.09	1.13	1.16	1.02
Leucine	---	3.27	3.39	3.42	3.06
Lysine	---	1.03	1.12	1.00	0.90
Methionine	---	0.58	0.58	0.54	0.49
Threonine	---	1.10	1.09	1.10	1.02
Tryptophan	---	0.19	0.22	0.22	0.21
Valine	---	1.40	1.46	1.50	1.34

[1] Values represent the mean of 1 sample analyzed 6 times.
[2] Dried distillers grains with solubles.

Table 2. Fatty acid analysis of low- and high-oil dried distillers grains with solubles (DDGS)

	Exp 1		Exp 2	
Fatty acid, % of total fat	5.4% oil DDGS	9.6% oil DDGS	9.4% oil DDGS	12.1% oil DDGS
Myristic (14:0)	0.08	0.08	0.07	0.06
Palmitic (16:0)	14.87	14.65	14.11	13.88
Palmitoleic (16:1)	0.14	0.13	0.13	0.13
Stearic (18:0)	2.33	2.15	2.01	1.98
Elaidic (18:1*t9*)	0.08	0.07	0.07	0.07
Oleic (18:1*n9*)	26.14	26.57	26.01	25.46
Linoleic (18:2)	52.43	52.47	53.85	54.96
Linolenic (ω18:3)	1.54	1.62	1.50	1.44
Arachidic (20:0)	0.41	0.44	0.41	0.38
Gadoleic acid (C20:1n9)	0.42	0.44	0.41	0.36
Docosanoic (22:0)	0.23	0.24	0.22	0.22
Lignoceric (24:0)	0.37	0.32	0.33	0.30
Other fatty acids	0.96	0.82	0.88	0.76
Total SFA, %[1]	18.29	17.88	17.15	16.82
Total MUFA, %[2]	26.78	27.21	26.62	26.02
Total PUFA, %[3]	53.97	54.09	55.35	56.40
UFA:SFA ratio[4]	4.41	4.55	4.78	4.90
PUFA:SFA ratio[5]	2.95	3.02	3.22	3.35
Iodine value, %[6]	131.8	132.2	133.3	134.3

[1] Total SFA = ([C14:0] + [C16:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.
[2] Total MUFA = ([C16:1] + [C18:1 *t*-9] + [C18:1n-9] + [C20:1]); brackets indicate concentration.
[3] Total PUFA = ([C18:2] + [C18:3]); brackets indicate concentration.
[4] UFA:SFA = (total MUFA + total PUFA)/total SFA.
[5] PUFA:SFA = total PUFA/total SFA.
[6] Calculated as iodine value = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785); brackets indicate concentration.

Table 2. Bulk densities and particle size of dried distillers grains with solubles (DDGS) sources (as-fed basis)[1]

	Source and DDGS, %			
	Exp. 1		Exp. 2	
Item	5.4% oil DDGS	9.6% oil DDGS	9.4% oil DDGS	12.1% oil DDGS
Bulk density, lb/bu[2]	45.7	42.7	43.8	40.2
Particle size, μ	371	562	744	687

[1] Ingredient samples were taken from every delivery (Exp. 1) and were combined so that a composite sample could be evaluated. In Exp. 2, all diets were made from single batches of both DDGS sources; therefore, a representative sample was analyzed.

[2] Bulk densities represent the mass per unit volume. Diet samples were taken from the tops of feeders during each phase.

Table 3. Phase 1 diet compositions (as-fed basis)[1]

	Exp. 1			Exp. 2		
	Control	DDGS source,[2] % inclusion		Control	DDGS source,[3] % inclusion	
Item	0	20	40	0	20	40
Ingredient, %						
Corn	76.2	59.4	41.9	74.2	58.1	41.8
Soybean meal (46.5% CP)	21.5	18.5	15.8	22.9	19.25	15.7
5.4 or 9.6% oil DDGS	-	20.0	40.0	-	-	-
9.4 or 12.1% oil DDGS	-	-	-	-	20.0	40.0
Monocalcium P (21% P)	0.43	0.03	-	0.90	0.45	-
Limestone	0.90	1.10	1.38	0.95	1.2	1.45
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix[4]	0.10	0.10	0.10	0.30	0.30	0.30
L-lysine HCl	0.48	0.53	0.58	0.23	0.27	0.31
DL-methionine	0.04	-	-	0.02	-	-
L-threonine	0.07	0.01	-	0.03	-	-
Phytase	0.02	0.01	0.01	0.13	0.13	0.13
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible (SID) amino acids, %						
Lysine	0.95	0.95	0.95	0.95	0.95	0.95
Isoleucine:lysine	62	68	75	65	70	74
Leucine:lysine	139	179	219	150	177	205
Methionine:lysine	29	30	34	29	32	37
Met & Cys:lysine	55	59	66	57	61	66
Threonine:lysine	60	60	65	61	63	69
Tryptophan:lysine	18	18	18	18	18	18
Valine:lysine	69	79	89	75	82	90
Total lysine, %	1.07	1.10	1.13	1.06	1.10	1.14
ME, kcal/lb	1,505	1,483	1,453	1,508	1,511	1,515
SID lysine: ME, g/Mkcal	2.86	2.91	2.96	2.86	2.85	2.84
CP, %	17.0	19.7	22.5	17.2	19.6	22.0
Ca, %	0.48	0.48	0.57	0.63	0.63	0.63
P, %	0.44	0.44	0.53	0.55	0.53	0.51
Available P, %	0.27	0.27	0.37	0.38	0.38	0.38

[1] Phase 1 diets were fed in meal form from d 0 to 27 (Exp. 1) and d 0 to 26 (Exp. 2).
[2] Diets included both 5.4 and 9.6%-oil dried distillers grains with solubles (DDGS) sources fed at 20 and 40% of the diet.
[3] Diets included both 9.4 and 12.1%-oil DDGS sources fed at 20 and 40% of the diet.
[4] Provided per pound of premix in Exp.1: 2,000,000 IU vitamin A; 250,000 IU vitamin D_3; 8,000 IU vitamin E; 800 mg vitamin K; 1,500 mg riboflavin; 5,000 mg pantothenic acid; 9,000 mg niacin; 7 mg vitamin B_{12}; 12 g Mn from manganese oxide; 50 g Fe from iron sulfate; 50 g Zn from zinc sulfate; 5 g Cu from copper sulfate; 90 mg I from calcium iodate; and 90 mg Se from sodium selenite. Normal K-State vitamin and trace mineral premixes were used in Exp. 2.

Table 4. Phase 2 diet compositions (as-fed basis)[1]

	Exp. 1			Exp. 2		
	Control	DDGS source,[2] % inclusion		Control	DDGS source,[3] % inclusion	
Item	0	20	40	0	20	40
Ingredient, %						
Corn	79.8	62.8	45.4	79.6	63.3	47.1
Soybean meal (46.5% CP)	18.2	15.3	12.4	17.7	14.2	10.5
5.4 or 9.6% oil DDGS	-	20.0	40.0	-	-	-
9.4 or 12.1% oil DDGS	-	-	-	-	20.0	40.0
Monocalcium P (21% P)	0.40	-	-	0.80	0.35	-
Limestone	0.90	1.10	1.35	0.98	1.25	1.43
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin and trace mineral premix[4]	0.10	0.10	0.10	0.25	0.25	0.25
L-lysine HCl	0.35	0.38	0.44	0.20	0.24	0.29
DL-methionine	0.01	-	-	0.01	-	-
L-threonine	0.03	-	-	0.02	-	-
Phytase	0.02	0.01	0.01	0.13	0.13	0.13
Total	100	100	100	100	100	100
Calculated analysis						
Standardized ileal digestible (SID) amino acids, %						
Lysine	0.80	0.80	0.80	0.80	0.80	0.80
Isoleucine:lysine	66	74	82	67	72	77
Leucine:lysine	156	203	250	163	196	228
Methionine:lysine	29	33	38	29	35	41
Met & Cys:lysine	58	66	75	60	66	73
Threonine:lysine	61	65	71	62	66	73
Tryptophan:lysine	18	18	18	18	18	18
Valine:lysine	75	87	98	78	87	96
Total lysine, %	0.91	0.94	0.98	0.90	0.94	0.98
ME, kcal/lb	1,506	1,484	1,455	1,510	1,514	1,517
SID lysine: ME, g/Mkcal	2.41	2.45	2.49	2.40	2.40	2.39
CP, %	15.5	18.3	21.1	15.2	17.6	20.0
Ca, %	0.47	0.47	0.55	0.60	0.61	0.60
P, %	0.42	0.42	0.51	0.51	0.49	0.49
Available P, %	0.26	0.26	0.36	0.35	0.35	0.38

[1] Phase 2 diets were fed in meal form from d 27 to 61 (Exp. 1) and d 26 to 54 (Exp. 2).
[2] Diets included both 5.4 and 9.6%-oil dried distillers grains with solubles (DDGS) sources fed at 20 and 40% of the diet.
[3] Diets included both 9.4 and 12.1%-oil DDGS sources fed at 20 and 40% of the diet.
[4] Provided per pound of premix in Exp.1: 2,000,000 IU vitamin A; 250,000 IU vitamin D3; 8,000 IU vitamin E; 800 mg vitamin K; 1,500 mg riboflavin; 5,000 mg pantothenic acid; 9,000 mg niacin; 7 mg vitamin B12; 12 g Mn from manganese oxide; 50 g Fe from iron sulfate; 50 g Zn from zinc sulfate; 5 g Cu from copper sulfate; 90 mg I from calcium iodate; and 90 mg Se from sodium selenite. Normal K-State vitamin and trace mineral premixes were used in Exp. 2.

Table 5. Phase 3 diet compositions (as-fed basis)[1]

	Exp. 1			Exp. 2		
	Control	DDGS source,[2] % inclusion		Control	DDGS source,[3] % inclusion	
Item	0	20	40	0	20	40
Ingredient, %						
Corn	76.6	59.4	42.0	83.1	66.9	50.6
Soybean meal (46.5% CP)	21.4	18.6	15.7	14.4	10.8	7.2
5.4 or 9.6% oil DDGS	-	20.0	40.0	-	-	-
9.4 or 12.1% oil DDGS	-	-	-	-	20.0	40.0
Monocalcium P (21% P)	0.15	-	-	0.80	0.30	-
Limestone	0.85	1.10	1.38	0.88	1.15	1.30
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamine and trace mineral premix[4]	0.10	0.10	0.10	0.20	0.20	0.20
L-lysine HCl	0.38	0.43	0.48	0.18	0.22	0.27
DL-methionine	0.05	-	-	-	-	-
L-threonine	0.08	0.04	-	0.03	-	-
Phytase	0.02	0.01	0.01	0.13	0.13	0.13
Ractopamine HCl, 10 ppm[5]	0.03	0.03	0.03	-	-	-
Total	100	100	100	100	100	100
Standardized ileal digestible (SID) amino acids, %						
Lysine	0.90	0.90	0.90	0.70	0.70	0.70
Isoleucine:lysine	65	72	79	68	75	81
Leucine:lysine	148	190	231	175	213	250
Methionine:lysine	32	31	36	31	38	44
Met & Cys:lysine	59	62	70	63	71	79
Threonine:lysine	65	67	69	65	69	76
Tryptophan:lysine	18	18	18	18	18	18
Valine:lysine	73	83	94	81	92	102
Total lysine, %	1.02	1.05	1.08	0.79	0.83	0.87
ME, kcal/lb	1,509	1,482	1,453	1,513	1,517	1,520
SID lysine: ME, g/Mkcal	2.70	2.75	2.80	2.10	2.09	2.09
CP, %	16.9	19.7	22.4	13.9	16.3	18.8
Ca, %	0.42	0.48	0.57	0.55	0.56	0.55
P, %	0.38	0.44	0.53	0.50	0.47	0.48
Available P, %	0.21	0.26	0.37	0.35	0.34	0.37

[1] Phase 3 diets were fed in meal form from d 61 to 82 (Exp. 1) and d 54 to 75 (Exp. 2).
[2] Diets included both 5.4 and 9.6%-oil dried distillers grains with solubles (DDGS) sources fed at 20 and 40% of the diet.
[3] Diets included both 9.4 and 12.1%-oil DDGS sources fed at 20 and 40% of the diet.
[4] Provided per pound of premix in Exp.1: 2,000,000 IU vitamin A; 250,000 IU vitamin D3; 8,000 IU vitamin E; 800 mg vitamin K; 1,500 mg riboflavin; 5,000 mg pantothenic acid; 9,000 mg niacin; 7 mg vitamin B12; 12 g Mn from manganese oxide; 50 g Fe from iron sulfate; 50 g Zn from zinc sulfate; 5 g Cu from copper sulfate; 90 mg I from calcium iodate; and 90 mg Se from sodium selenite. Normal K-State vitamin and trace mineral premixes were used in Exp. 2.
[5] Paylean; Elanco Animal Health (Greenfield, IN).

Table 6. Diet composition, Exp. 3, as-fed basis[1]

Ingredient, %	Corn-basal diet
Corn	96.90
Limestone	2.30
Salt	0.40
Vitamin premix	0.25
Trace mineral premix	0.15

[1]A total of 12 pigs (PIC 327 × 1050; initially 11,6 lb BW) were used in a 6-wk study to provide 12 observations per treatment. The basal diet was blended 50/50 with the 4 dried distillers grains with solubles sources to provide the other experimental diets.

Table 7. Effects of low- vs. high-oil dried distillers grains with solubles (DDGS) on growth performance of finishing pigs (Exp.1)[1]

	Control	5.4% oil DDGS		9.6% oil DDGS			5.4% oil DDGS		9.6% oil DDGS		5.4 vs.	DDGS level		Source × level	
	0	20	40	20	40	SEM	Linear	Quad.	Linear	Quad.	9.6% Oil	Linear	Quad.	Linear	Quad.
d 0 to 82															
ADG, lb	2.28	2.29	2.24	2.27	2.27	0.02	0.29	0.33	0.73	0.84	0.96	0.42	0.62	0.47	0.36
ADFI, lb	5.73	5.93	6.07	5.69	5.82	0.07	0.002	0.69	0.40	0.36	0.002	0.02	0.73	0.02	0.30
Feed/gain	2.52	2.59	2.71	2.51	2.57	0.03	0.001	0.62	0.21	0.37	0.0003	0.001	0.36	0.001	0.76
BW, lb															
d 0	101.7	101.6	101.6	101.7	101.7	1.38	0.96	0.99	0.98	0.98	0.97	0.97	0.99	0.99	0.98
Final BW, lb	285.5	286.0	283.1	285.0	286.0	2.40	0.50	0.57	0.87	0.80	0.69	0.77	0.83	0.40	0.52

[1] A total of 1,198 pigs (PIC 337 × 1050, initially 20.9 lb) were used in this 82-d study with 26 to 27 pigs per pen and 9 pens per treatment.

Table 8. Effects of low- vs. high-oil dried distillers grains with solubles (DDGS) on carcass characteristics of finishing pigs (Exp.1)[1]

	CS[2]	5.4% oil DDGS		9.6% oil DDGS			5.4% oil DDGS		9.6% oil DDGS		5.4 vs.	DDGS level		Source × level	
	0	20	40	20	40	SEM	Linear	Quad.	Linear	Quad.	9.6% Oil	Linear	Quad.	Linear	Quad.
HCW, lb	210.2	207.1	204.7	205.4	206.7	1.78	0.03	0.88	0.16	0.18	0.93	0.04	0.32	0.43	0.35
Carcass yield, %[3]	76.23	75.99	74.92	75.43	75.21	0.46	0.05	0.47	0.13	0.62	0.78	0.05	0.89	0.66	0.34
Backfat depth, in.[4]	0.61	0.62	0.61	0.60	0.62	0.01	0.89	0.81	0.86	0.50	0.82	0.99	0.77	0.75	0.48
Loin depth, in.[4]	2.82	2.76	2.79	2.76	2.80	0.03	0.36	0.18	0.59	0.09	0.84	0.40	0.05	0.67	0.75
Lean, %[4]	57.92	57.74	57.91	57.92	57.84	0.22	0.97	0.49	0.80	0.89	0.78	0.87	0.72	0.83	0.53
Fat-free lean index[4]	51.26	51.21	51.29	51.38	51.22	0.17	0.88	0.74	0.89	0.49	0.75	0.99	0.81	0.77	0.43
Jowl iodine value (IV)[5]	67.36	70.92	76.68	72.02	78.73	0.96	<0.001	0.32	<0.001	0.27	0.06	<0.001	0.17	0.06	0.96
Belly IV[5]	62.10	67.84	73.52	70.88	76.18	0.96	<0.001	0.98	<0.001	0.11	0.002	<0.001	0.29	0.03	0.24
Backfat IV[5]	66.48	70.30	75.79	71.74	78.83	0.74	<0.001	0.34	<0.001	0.25	0.001	<0.001	0.94	0.001	0.94

[1] A total of 1,198 pigs (PIC 337 × 1050, initially 20.9 lb) were used in this 82-d study. There were 26 or 27 pigs per pen and 9 pens per treatment.
[2] Refers to the control, corn-soybean meal diet.
[3] Percentage yield was calculated by dividing HCW by live weight obtained at the packing plant.
[4] Adjusted by using HCW as a covariate.
[5] Calculated as IV = [C16:1] × 0.9502 + [C18:1] × 0.8598 + [C18:2] × 1.7315 + [C18:3] × 2.6152 + [C20:1] × 0.7852 + [C20:4] × 3.2008; brackets indicate concentration.

Table 9. Effects of low- vs. high-oil dried distillers grains with solubles (DDGS) on growth performance of finishing pigs (Exp.2)[1]

	DDGS source and % of diet															
	Control	9.4% oil DDGS		12.1% oil DDGS			9.4% oil DDGS		12.1% oil DDGS		9.4 vs. 12.1%	DDGS level		Source × level	
Item	0	20	40	20	40	SEM	Linear	Quad.	Linear	Quad.	Oil	Linear	Quad.	Linear	Quad.
d 0 to 90															
ADG, lb	2.22	2.20	2.21	2.31	2.16	0.04	0.23	0.01	0.79	0.70	0.34	0.40	0.11	0.34	0.02
ADFI, lb	6.27	6.07	6.01	6.18	5.90	0.12	0.04	0.51	0.14	0.63	0.96	0.04	0.90	0.54	0.38
Feed/gain	2.82	2.76	2.72	2.67	2.73	0.04	0.12	0.03	0.08	0.82	0.31	0.06	0.11	0.85	0.13
BW, lb															
d 0	102.3	102.0	101.9	102.0	102.2	2.9	0.99	0.95	0.93	0.97	0.96	0.95	0.95	0.95	0.99
Final BW, lb	268.8	267.8	268.6	275.5	264.2	3.7	0.38	0.06	0.96	0.85	0.66	0.59	0.25	0.41	0.10

[1]A total of 270 pigs (PIC 327 × 1050, initially 20.9 lb BW) were used in this 75-d study with 8 pigs per pen and 7 pens per treatment.

Table 10. Effects of low- vs. high-oil dried distillers grains with solubles (DDGS) on carcass characteristics of finishing pigs (Exp. 2)[1]

	DDGS source and % of diet														
	CS[2]	9.4% oil DDGS		12.1% oil DDGS			9.4% oil DDGS		12.1% oil DDGS		9.4% vs. 12.1%	DDGS level		Source × level	
	0	20	40	20	40	SEM	Linear	Quad.	Linear	Quad.	Oil	Linear	Quad.	Linear	Quad.
HCW, lb	195.2	193.0	191.1	196.5	186.5	2.44	0.02	0.06	0.24	0.97	0.81	0.04	0.23	0.18	0.14
Carcass yield, %[3]	72.59	71.94	71.02	72.30	71.16	0.18	0.001	0.54	0.001	0.06	0.17	0.001	0.10	0.59	0.31
Backfat depth, in.[4]	18.6	19.1	18.1	18.3	18.25	0.49	0.62	0.79	0.46	0.23	0.52	0.47	0.53	0.81	0.25
Loin depth, in.[4]	61.3	60.2	60.4	60.0	59.90	0.87	0.26	0.60	0.46	0.54	0.73	0.28	0.45	0.70	0.93
Lean, %	53.72	53.55	53.51	53.29	53.65	0.30	0.63	0.86	0.88	0.29	0.84	0.72	0.41	0.74	0.49
Jowl fat iodine value[5]	66.80	73.08	77.47	73.38	80.01	0.42	0.001	0.07	0.001	0.96	0.002	0.001	0.25	0.0001	0.15

[1] A total of 270 pigs (PIC 327 × 1050, initially 21.1 lb BW) were used in this 75-d study. There were 8 pigs per pen and 7 pens per treatment.
[2] Refers to the control, corn-soybean meal treatment.
[3] Percentage yield was calculated by dividing HCW by live weight obtained at the farm before transport to the packing plant.
[4] Adjusted by using HCW as a covariate.
[5] Analyzed by near-infrared spectroscopy (Bruker MPA, Breman, Germany) at the plant for IV using the equation of Cocciardi et al. (2009).

Table 11. Energy values of corn and dried distillers grains with solubles (DDGS) sources and 7.6%-oil DDGS (Graham, 2013; as fed basis)

		Exp. 1		Exp. 2		Graham (2013)
Item, kcal/lb	Corn	5.4% oil DDGS	9.6% oil DDGS	9.4% oil DDGS	12.1% oil DDGS	7.6% oil DDGS
GE	1,756	1,972	2,108	2,142	2,224	2,080
DE	1,594	1,550	1,674	1,741	1,694	1,522
ME[1]	1,567	1,459	1,582	1,650	1,606	1,430

[1] Eqation 1-6 from NRC (2012) with values converted from kcal/kg to kcal/lb.

Table 12. Comparison of corn and DDGS source digestibilities[1]

		Exp. 1		Exp. 2	
Item, %	Corn	5.4% oil DDGS	9.6% oil DDGS	9.4% oil DDGS	12.1% oil DDGS
DM	93.3[a]	70.0[b]	73.6[b]	73.3[b]	71.9[b]
GE	91.1[a]	78.6[bc]	79.4[bc]	81.3[b]	76.1[c]
CP	85.5[a]	78.6[b]	86.3[a]	88.4[a]	76.0[b]
Ether extract	21.8[c]	67.0[ab]	61.8[b]	71.2[ab]	75.6[a]
ADF	59.4[c]	62.8[c]	79.3[ab]	74.9[b]	82.2[a]
NDF	59.9[b]	54.8[bc]	72.0[a]	61.5[b]	51.4[c]
CF	47.4[d]	45.3[d]	53.5[c]	72.1[a]	63.4[b]

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$).
[1] A total of 12 pigs were used to achieve 12 replications per treatment.

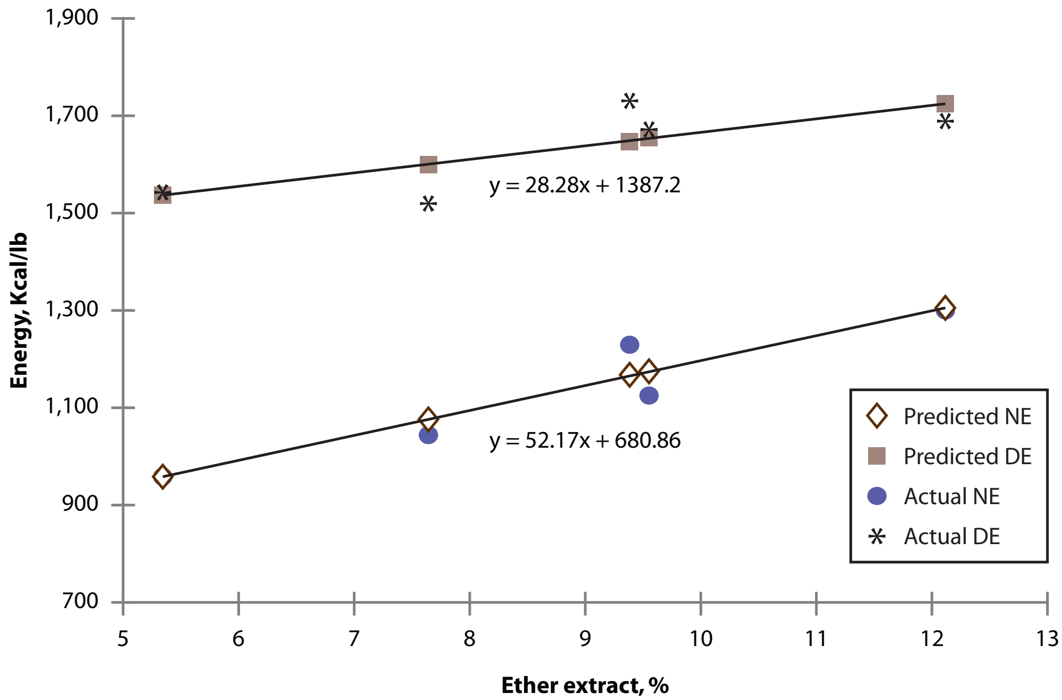

Figure 1. Predicted and actual DE and NE values of dried distillers grains with solubles sources varying in oil content (as-fed basis).