FINAL REPORT

PROJECT TITLE: Final validation of reduced-oil DDGS energy prediction equations for swine and widespread industry implementation**.**

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ABSTRACT

The widespread implementation of corn oil extraction in the U.S. ethanol industry has led to perceptions among DDGS marketers and nutritionists that the resulting reduced-oil DDGS has less metabolizable energy (ME) than traditional high-oil DDGS sources. Our previous research showed a very poor association between oil content of DDGS and ME content for swine. As a result, ME prediction equations, based on chemical composition of DDGS, were developed and validated to accurately estimate ME content among DDGS sources with variable oil content for swine. The objective of this study was to conduct a final validation that oil content of DDGS does not affect ME content for swine. Our results verified this when comparing 3 DDGS sources containing 14, 10, and 6% crude fat but similar predicted ME content. These results are invaluable for educating DDGS marketers and end-users that ME content can be accurately be predicted using our validated prediction equations even though oil and chemical composition varies among sources. This benefits corn farmers because DDGS price should not be discounted because of reduced oil content, and provides convincing evidence to maintain existing diet inclusion rates for DDGS in swine. Ultimately, these results will help maintain demand in domestic and exports markets for using U.S. DDGS in swine diets.

INTRODUCTION

Use of alternative feed ingredients decreases diet cost and improves nutritional efficiency of swine feeding programs (Woyengo et al., 2014). However, issues with environmental impact of indigestible nutrients and variability in nutrient and energy content limit the inclusion levels of alternative feed ingredients. Corn distillers dried grains with solubles (DDGS) has 3 times more NDF content compared with corn (NRC, 2012) which has a negative impact on digestibility of other nutrients such as proteins and lipids (Kass et al., 1980; Bach Knudsen and Hansen, 1991; Chen et al., 2013). As a result, a large proportion of energy contained in DDGS is not utilized by the pig.

Ethanol plants also began extracting oil from thin stillage prior to manufacturing DDGS and consequently variability in nutrient and ME content among sources increased (Kerr et al., 2013). This variable ME content limits utilization of DDGS in swine diets. Pigs fed corn soybean meal diets supplemented with 40% corn DDGS that have an oil content less than 6% (as measured by ether extract) have less G:F than pigs fed a control corn soybean meal diet (Wu et al., 2016). This decrease of G:F appears to be the result of overestimating the ME content of DDGS with oil content less than 6%.

OBJECTIVE AND GOAL STATEMENTS

We hypothesized that DDGS sources with oil content less than 6% will have less concentration of DE and ME than DDGS with > 10% oil. Therefore, the objective of this study was to determine if DE and ME content differs among pigs fed DDGS diets with increasing lipid content.

MATERIALS AND METHODS

Animal Management

The experimental protocols used in this study were reviewed and approved by the Institutional Animal Care and Use Committee at University of Minnesota (St. Paul, MN). This experiment was conducted over two 18-d periods at University of Minnesota - Research and Outreach Center (Waseca, MN). One group of 32 gilts (initial BW = 107.7 ± 9.0 kg), which were the offspring of sows (Landrace × Yorkshire; Genetically Advanced Pigs, Winnipeg, Manitoba) mated to Duroc boars (Compart’s Boar Store, Nicollet, MN), were moved into an environmentally controlled room and placed individually in metabolism crates (1.2 × 2.4 m) that allowed for separate collection of feces and urine. Ambient room temperature was maintained at about 18.3 °C, and lighting was provided from 700 to 1800. Crates were equipped with a stainless steel feeder and a nipple drinker to provide pigs with *ad libitum* access to water.

Feed Ingredients and Diets

Gilts were allotted randomly to 1 of 4 diets, resulting in 8 replicates for pigs per treatment. We selected the 3 sources of DDGS with different oil content that were fed to pigs in the experiment of Wu et al. (2016), which are 1) low oil DDGS (5.7 % ether extract; **EE**, DM basis), 2) medium oil DDGS (8.2% EE), and 3) high oil DDGS (12.4 % EE), were selected for this study (Table). Dietary treatments consisted of 1) corn-soybean meal based control diet (**CON**), 2) CON + 40% low oil DDGS (**LO**), 3) CON + 40% medium oil DDGS (**MO**), and 4) CON + 40% high oil DDGS (**HO**) and were formulated to meet NRC requirements (Table). All diets were fed in meal form with 0.5% digestion marker (TiO_2) added in each diet for calculating total tract digestibility of nutrients. The distribution and standard deviation of the size of particles were analyzed using ANSI/ASAE Standards (2008) method S319.4. The actual geometrical mean particle size for each diet was 660 ± 3.9 µm (CON), 600 ± 3.0 µm (CO), 530 ± 3.25 (MO), and 890 ± 3.2 (HO), and all diets were fed in meal form. Pigs were fed twice daily a total amount of feed equivalent to 3.0% of their initial BW for 18 days, which approximated *ad libitum* feed intake for pigs at this BW. Actual feed disappearance was calculated as the difference between the amounts of feed added minus the amount of feed not consumed.

Sample Collection

During d-15 to d-18 collection period, stainless steel wire screens and stainless steel buckets containing 30 mL of 6 N HCl were placed under each metabolism crate allowing collection of urine from each pig. Fresh feces were collected directly from the anus into a plastic bag. Feces and 5% of urine were collected twice daily during each meal, weighed, and stored at -20 °C until the end of the experiment. Feces from each pig were pooled, dried in forced air oven at 60° C, weighed, ground to pass through a 1 mm screen (Wiley No. 4 Laboratory Mill, Arthur H Thomas Co., Philadelphia, PA), and mixed to obtain a representative sample for analysis. Energy and nutrient digestibility and excretion were calculated by using this portion of the feces. Likewise, urine samples were thawed, weighed, and pooled within pig to collect a representative sample for analysis. Energy and nutrient balance was calculated by using this portion of the urine.

During the d-14, a small part of fresh fecal and urine output (without adding HCl) were collected from each pig, added to 32 individual plastic bottles, manually mixed to simulate fresh manure and stored at -20 °C until the end of all collections. The ratio of feces to urine was 0.20 for control diet and 0.26 for experimental diets, and was calculated based on daily fecal and urine output observed in pigs with fed similar dietary treatments by Spiehs et al. (2012).

Chemical Analysis and Calculations

Feed ingredient, diet, fecal, and urine samples were analyzed at Midwest Laboratories, Inc., Omaha, NE (Table). To determine DE and ME content, GE of feed ingredient, diet, fecal, and urine samples were determined following standard method D5865-13 (ASTM, 2013). The DM content of feed ingredients, diets and feces were analyzed following official method 930.15 (AOAC, 2005). The concentration of CP of feed ingredients, diets, feces and urine were analyzed following official method 990.03 (AOAC, 2005). The concentration of EE in feed ingredients and diets and diets was analyzed following official method 945.16 (AOAC, 2005). The concentration of acid hydrolyzed ether extract (**AEE**) in feed ingredients, diets, and feces was analyzed following official method 945.02 (AOAC, 2005). The concentration of NDF in feed ingredients, diets and feces was analyzed using ANKOM Tech. method 13. The ash content of samples were determined by AOAC (2005) official method 942.05. The concentration of titanium in diets and feces was analyzed by Wavelength Dispersive X-ray Fluorescence (Jenkins, 2006).

Apparent total tract digestibility (**ATTD**) of energy, DM, CP, EE, and NDF of each diet were calculated using the different procedure of index method described by Adeola, (2001). Energy and nutrient digestibility of diets were calculated using equations:

$$\text{Energy digestibility, \%} = 100 - 100 \times \left(\frac{\text{\% index compound in feed} \times \text{GE of feces}}{\text{\% index compound in feces} \times \text{GE of feed}}\right).$$

$$\text{Nutrient digestibility, \%} = 100 - 100 \times \left(\frac{\text{\% index compound in feed} \times \text{\% nutrient in feces}}{\text{\% index compound in feces} \times \text{\% nutrient in feed}}\right).$$

Apparent total tract digestibility of each DDGS ingredients were calculated using the procedure described by Adeola (2001). Energy and nutrient digestibility of feed ingredients were calculated using equation:

$$\text{Energy or nutrient digestibility, \%} = 100 \times \left[\frac{(\text{T x t}) - (\text{B x b})}{\text{a}}\right];$$

where: T is the digestibility of total diet; t is the amount of the component in the test diet consumed; B is the digestibility of the component in control diet; b is the amount of component in the control diet consumed; and a is the amount of the component in the test feed ingredient added to the control diet t = b + a. The digestibility of the control diet, B, and the test diet, T, were determined by the procedure of index method described above.

The concentration of ME (kcal/kg DM basis) was calculated for low, medium, and high oil DDGS using the chemical composition of each ingredient and the equations developed by (Noblet and Perez, 1993; Anderson et al., 2012; NRC, 2012)

Statistical Analysis

The experiment was designed as a completely randomized design, with the individual pig or manure container serving as the experimental unit. With 4 dietary treatments and 32 pigs, there were for 8 replicates per treatment. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with individual pig as a random effect and diet composition as fixed effects. Results were reported as least squares means. Comparisons among treatments were performed using the PDIFF option of SAS with the Tukey-Kramer adjustment for multiple comparisons. Treatment effects were considered significant if $P < 0.05$, and trends are reported if $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

Results

All pigs remained healthy during the study and consumed their respective daily ration thus no data were removed from the experiment. There were differences in the chemical composition of DDGS that were not only on the concentration of AEE, but also other nutrients. As expected the greatest variation in nutrient composition among sources of DDGS was the concentration of EE (CV = 41.5%). This variation in EE content was followed by variation in NDF content (CV = 19.7%) and least CP (CV = 3.8%). The mean particle size (µm) of high oil DDGS (1,300) was greater than medium oil (370) and low oil (390) DDGS. In agreement with the content of oil in DDGS, LO diet contained less EE (3.77%) than MO diet (5.01%) and HO diet (7.75%). But the analyzed concentration of NDF was greater in HO diet (19.20%) than MO diet (17.50%) and LO diet (17.80%).

Intake, Apparent Total Tract Digestibility, and Excretion of Nutrients in Diets

As set by the restricted feeding plan, there were no differences in DM intake among treatments (data not shown). The ATTD of DM in CON was greater ($P < 0.05$) than all diets with DDGS and there were no differences ($P > 0.10$) among LO, MO, or HO diets (Table). The ATTD of CP between CON and LO was not different, while ATTD of CP in MO was intermediate, and ATTD of CP in HI was the least (P < 0.05). Also, ATTD of AEE was less in CON than all 3 diets with DDGS (LO, MO, and HO). The ATTD of AEE of the HO diet was greater ($P < 0.01$) than the MO diet, and this was greater than LO diet. Finally, the ATTD of NDF was not different among diets.

The GE content in diets with DDGS was greater than GE content in the CON diet. The DE content in the CON diet was greater ($P < 0.05$) than the LO and MO diets, but it was not different from the HO diet. Also, the content of ME in the CON diet was greater ($P < 0.01$) than all diets with DDGS (LO, MO, and HO) and there were no differences in ME content among diets with DDGS. As expected all diets with DDGS (LO, MO, and HI) has less DE:GE ME:DE, and ME:GE than CON.

Intake, Apparent Total Tract Digestibility, and Excretion of Nutrients among sources of DDGS

The differences in ATTD of nutrients among LO, MO, and HO diets was the result of differences among sources of DDGS. There were no differences in calculated ATTD of DM among low, medium, or high oil DDGS (Table). The ATTD of CP was less ($P < 0.01$) in high oil DDGS than medium oil DDGS and ATTD of CP in medium oil DDGS was less than low CP DDGS. The ATTD of AEE was less ($P < 0.05$) in low oil DDGS than medium oil DDGS and high oil DDGS had the greatest ATTD of EE. There were no differences in the ATTD of starch or ash among low, medium, or high oil DDGS. There were no differences in the content of DE or ME among sources of DDGS with low, medium, or high oil content. Likewise, there were no differences in DE:GE, ME:DE, or ME:GE ratios among sources of DDGS.

DISCUSSION

Nutrient Composition

The content of nutrients is an important first step towards correct characterization of the nutritional value of feed ingredients. Variability in nutrient concentration among sources of a feed ingredient may be caused by multiple factors. Analytical differences among laboratories, differences in procedures, and also differences in sampling methods all contribute to differences in reported nutrient content (Kerr et al., 2013). The nutrient composition of corn and soybean meal used in this experiment is in agreement with values reported in NRC (2012). The concentration GE in low, medium, and high oil DDGS was within the range reported in Anderson et al. (2012), NRC (2012), and Kerr et al. (2013). However, the low oil DDGS in the current experiment had greater concentration of GE (6 to 12%, respectively) than the low oil DDGS used in Anderson et al. (2012) and Kerr et al. (2013). The concentration CP in low, medium, and high oil DDGS was within the range reported in Anderson et al. (2012), NRC (2012), and Kerr et al. (2013). The concentration of CP and EE analyzed in the current experiment and for the experiment of Wu et al. (2016) were different because these samples were analyzed in 2 different laboratories.

Nutrient digestibility

The overall contribution of nutrients towards DE or ME of the diet is affected by the content of nutrients, but also by the digestibility of these nutrients. Clearly, there were differences in the ATTD of CP among sources of DDGS. The reason for these differences may be related to the fact that high oil DDGS has greater content of NDF and also greater particle size, both factors that affect the ATTD of CP. Kerr et al. (2013) reported that the ATTD of CP tended to decrease as NDF content of DDGS increased. There are multiple modes of action thereby NDF can decrease digestibility of CP, including increasing endogenous N losses, reducing CP activity of degrading enzymes, and decreasing contact between enzymes and substrate (Schulze et al., 1994). Studies from (Kass et al., 1980; Sauer et al., 1991; Chen et al., 2013) reported that digestibility of CP decreases in diets containing increasing NDF content. Kerr et al. (2013) reported the NDF content and the ATTD of N from 15 DDGS sources. We calculated the correlation between NDF content and ATTD of CP. We observed that the ATTD of CP decreased ($r = -0.51$) as NDF content of DDGS increased among all 15 DDGS sources. In addition, the variation in ATTD of N may be caused by the difference in nutrient content of corn sources used to produce DDGS as well as differenced in the drying processes of ethanol plants which may increase the production of Maillard by-products (Cromwell et al., 1993; Almeida et al., 2013).

The greater content of NDF in the high oil DDGS diet also may decrease the digestibility of oil. In fact, we made a calculation to estimate the correlation between the content of NDF in DDGS and the ATTD of EE. Similar to the ATTD of N, we estimated that the ATTD of EE decreased as NDF content of DDGS increased ($r = -0.46$) when using data from Kerr et al. (2013). These observations are well in agreement with observations from other groups that suggest that NDF content in DDGS decreases the ATTD of AEE (Kil et al., 2010). In the present study, the digestibility of acid hydrolyzed ether extract was correlated with the content of oil in DDGS, where the greater content of oil in DDGS, the greater calculated ATTD of AEE. The reason that ATTD of AEE in low oil DDGS is negative is the product of the endogenous losses of fat. When pigs are fed low fat diets, the proportional effect of endogenous losses is greater, and this apparent total tract digestibility estimates are not a reflection of the true digestibility of nutrients (Stein et al., 2007; Kim et al., 2013).

Energy Balance

In the literature, Anderson et al. (2012) reported ME values of 7 DDGS sources with oil content from 3.15 to 11.98% EE, DM basis. The sample with the least concentration of oil (3.15%) had a ME content of 3,650 kcal/kg DM and this value was not different from the value observed in other sources of DDGS with greater oil content. Kerr et al. (2013) also reported ME values of 15 sources of DDGS with oil content ranging from 4.88 to 11.83% EE, DM basis. The sample with least concentration of oil (4.88%) had a ME concentration of 3,289 kcal/kg DM and this value was greater than ME in other sources of DDGS with greater content of oil. Therefore, authors conclude that the difference in ME values did not correspond to the EE concentrations of DDGS sources (Kerr et al., 2013). In the present study there were no differences in the concentration of ME among low, medium, and high oil DDGS. These observations are in agreement with Anderson et al. (2012), NRC (2012), and Kerr et al. (2013).

We observed a numerically lower concentration of ME in the low oil DDGS than in high oil DDGS, this lesser concentration of ME in DDGS with low oil compared with DDGS with medium and high oil is in agreement with less gain to feed ratio of growing pigs fed low oil DDGS in comparison with high oil DDGS (Wu et al., 2016). It is possible that in fact low oil DDGS in the current experiment in fact had less ME than high oil DDGS, but it is less than it can be experimentally measured.

There are several reasons why ME content in RO-DDGS is poorly predicted by oil content because the ME of a feed ingredient depends on multiple factors such as content and digestibility of nutrients such as CP and NDF. In fact, Kerr et al. (2013) observed that content of NDF in DDGS is highly correlated with ME content. In the present study, NDF content of the high oil DDGS source was greater than medium and low oil DDGS. The content of NDF decreases ME of feed ingredients, not only because NDF is less digestible than CP and oil, but also because NDF decreases digestibility of CP and oil.

Particle size is another important variable to effect DE or ME content in DDGS (Kerr et al., 2013). In the present study, the geometrical mean particle size of high oil DDGS (900 ± 1.9 μm) was more than 2 times greater compared with low oil (410 ± 2.0 μm) and medium oil DDGS (350 ± 2.2 μm). Liu et al. (2012) reported that the ME contribution of DDGS to the diet is increased by 13.6 kcal/kg DM for each 25 μm decrease in DDGS particle size from 818 to 308 μm. Based on his calculations, we estimated that the greater particle size in high oil DDGS sample would decrease ME content of DDGS by 400 kcal/kg DM. Therefore, in spite of greater oil content the high oil DDGS, it in fact has an ME content that was not different from low oil or medium oil DDGS.

CONCLUSIONS

To capture the complete value of using corn co-products in diets for swine, it is necessary to have accurate ME prediction estimates to manage the variability in nutrient content among sources. Metabolizable energy is a major component of the value of corn DDGS, and we did not observe an impact of oil content on the concentration of ME among sources of reduced oil DDGS. Therefore, the current equations we developed and validated are effective in estimating the content of ME among sources of reduced oil DDGS for swine.

EDUCATION, OUTREACH, AND PUBLICATIONS

Results from this study are being used extensively in all of Dr. Shurson’s presentations for U.S. Grains Council programs in Asia and Latin America, to educate DDGS end users on methods to capture full nutritional and economic value of DDGS in commercial swine diets, and increase diet inclusion rates of DDGS without risking reduced growth performance. The audiences consist of hunderds of traders, nutritionists, and major swine integrators in Japan, Taiwan, S. Korea, China, Vietnam, Thailand, Mexico, and Columbia.

Results will be submitted to a scientific journal for publication as well as trade magazines such as Feedstuffs, National Hog Farmer, and Pork among others.

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Table 1. Analyzed chemical concentration (DM basis) and geometrical mean particle size of corn, soybean meal, and corn distillers dried grains with solubles (DDGS) of low, medium, and high oil content[1]

	Feed ingredients[1]				
Item	Corn	Soybean meal	Low oil DDGS	Medium oil DDGS	High oil DDGS
GE, kcal/kg	4,440	4,700	.	.	.
DM, %	84.22	86.81	89.60	89.62	90.34
CP, %	8.55	53.90	34.28	33.37	31.63
Ether extract, %	3.81	1.31	6.55	10.99	15.75
Acid ether extract, %	.	.	.	.	.
Neutral detergent fiber, %	8.00	8.10	31.66	33.25	48.83
Acid detergent fiber, %	0.80	.	9.06	11.02	17.32
Ash, %	1.74		5.09	4.50	5.11
Particle size, µm	700	1,000	410	350	900

[1]The same samples of DDGS were used in the present study and in Wu et al. (2016).

Table 2. Ingredient composition, calculated and analyzed chemical concentration (DM basis), and geometrical mean particle size of experimental diets mixed with corn distillers dried grains with solubles (DDGS) of variable oil content

	Dietary treatment[1]			
Item	CON	LO	MO	HO
Ingredient composition, as-fed basis, %				
Corn	79.79	47.17	47.17	47.17
Soybean meal	17.86	10.56	10.56	10.56
Low oil DDGS	-	40.00	-	-
Medium oil DDGS	-	-	40.00	-
High oil DDGS	-	-	-	40.00
Titanium dioxide	0.05	0.05	0.05	0.05
Dicalcium phosphate	0.65	-	-	-
Limestone	0.92	1.57	1.57	1.57
Sodium chloride	0.30	0.30	0.30	0.30
Vitamin and trace mineral premix[2]	0.25	0.25	0.25	0.25
L-Lys HCl	0.18	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00
Calculated chemical composition, as is				
ME, kcal/kg	3,763	3,750	3,749	3,737
CP, %	16.36	23.40	23.03	22.37
Lys, %	0.95	1.02	1.03	0.99
SID Lys, %	0.83	0.77	0.79	0.75
SID Met+Cys, %	0.45	0.66	0.65	0.66
SID Thr	0.48	0.65	0.64	0.63
SID Trp	0.16	0.17	0.17	0.16
Ether extract, %	3.44	4.65	6.44	8.37
Neutral detergent fiber, %	9.85	18.52	19.15	23.88
Analyzed chemical composition				
DM, %	85.10	86.23	85.84	85.31
GE, kcal/kg	4,340	4,620	4,590	4,740
CP, %	17.60	24.80	21.90	22.60
Ether extract, %	2.66	3.77	5.01	7.75
Starch, %	56.59	36.01	35.18	32.98
Neutral detergent fiber, %	8.50	17.80	17.50	19.20
Ash, %	3.83	5.55	5.12	5.16
Geometrical mean particle size, µm	660±3.9	600±3.0	530±3.3	890±3.2

[1]CON = corn - soybean meal diet. LO = CON + 40% low oil DDGS. MO = CON + 40% medium oil DDGS. HO = CON + 40% high oil DDGS.

[2] The premix supplied the following nutrients per kg of diet: 11,023 IU of vitamin A as retinyl acetate; 2,756 IU of vitamin D_3; 22 IU of vitamin E as dl-alpha tocopheryl acetate; 4.41 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 9.92 mg of riboflavin; 55.11 mg of niacin; 33.07 mg of pantothenic acid (as D-calcium pantothenate); 992 mg of choline (as choline chloride); 0.06 mg of vitamin B_{12}; 14.3 mg of pyridoxine; 1.65 mg of folic acid; 2.20 mg of thiamine; 0.33 mg of biotin; 2.20 mg of I (as ethylenediamine dihydroiodide); 0.30 mg of Se (as

Na_2SeO_3); 299 mg of Zn (as $ZnSO_4$); 299 mg of Fe (as $FeSO_4$); 19.8 mg of Cu (as $CuSO_4$); and 17.6 mg of Mn (as MnO).

Table 3. Reference procedures for analyses of ingredients, diets, feces, and urine

Measurement	Method
GE[1]	ASTM (2013) standard method D5865-13
DM[1]	AOAC (2005) official method 930.15
CP[1]	AOAC (2005) official method 990.03
Ether extract[1]	AOAC (2005) official method 945.16
Acid hydrolysis ether extract[1]	AOAC (2005) official method 945.02
NDF[1]	ANKOM Tech. method No. 13
Ash[1]	AOAC (2005) official method 942.05
Titanium[1]	Wavelength Dispersive X-ray Fluorescence (Jenkins, 2006)
Particle size[1]	ANSI/ASAE Standards (2008) S319.4
Foaming characteristics[2]	Yan et al. (2014)

[1]Analyzed by Midwest Laboratories, Inc., Omaha, NE.

[2]Analyzed by University of Minnesota, Saint Paul, MN.

Table 4. Apparent total tract digestibility and energy balance (DM basis) of pigs fed corn and soybean meal diets supplemented with 40% corn distillers dried grains with solubles (DDGS) with different oil content

	Diet composition[1]					
Item	CON	LO	MO	HO	SEM	*P*
No. pigs	8	8	8	8	-	-
Apparent total tract digestibility, %						
DM	81.7[a]	72.1[b]	73.0[b]	72.0[b]	0.91	< 0.01
CP	77.5[a]	77.0[a]	74.3[b]	68.7[c]	0.86	< 0.01
Acid hydrolyzed fat	-65.0[d]	-13.4[c]	2.9[b]	39.0[a]	3.5	< 0.01
Neutral detergent fiber	32.3	33.5	37.5	44.9	4.1	0.12
Starch	99.7	99.3	99.4	99.5	0.2	0.18
Ash	12.5[b]	29.6[a]	27.2[a]	26.0[a]	3.2	< 0.01
Energy						
GE, kcal/kg	4,340	4,620	4,590	4,740	.	.
DE, kcal/kg	3,396[a]	3,249[b]	3,231[b]	3,314[ab]	42	0.02
ME, kcal/kg	3,303[a]	3,102[b]	3,105[b]	3,160[b]	44	< 0.01
DE/GE, %	78.3[a]	70.4[b]	70.4[b]	70.0[b]	0.9	< 0.01
ME/DE, %	97.3[a]	95.5[b]	96.1[b]	95.3[b]	0.3	< 0.01
ME/GE, %	76.2[a]	67.2[b]	67.7[b]	66.7[b]	0.9	< 0.01

[1]CON = corn - soybean meal diet. LO = CON + 40% low oil DDGS. MO = CON + 40% medium oil DDGS. HO = CON + 40% high oil DDGS.

[abc]Values within a row with different superscripts are different ($P < 0.05$).

Table 5. Apparent total tract digestibility and energy content (DM basis) of corn distillers dried grains with solubles (DDGS) with different oil content.

	DDGS sources[1]				
Item	Low oil	Medium oil	High oil	SEM	*P*
Apparent total tract digestibility, %					
DM	72.1	73.0	72.0	1.4	0.75
CP	77.0[a]	74.3[b]	68.7[c]	1.3	< 0.01
Acid hydrolyzed fat	-13.4[c]	2.9[b]	39.0[a]	3.9	< 0.01
Neutral detergent fiber	33.5	37.5	44.9	6.0	0.18
Starch	99.3	99.4	99.5	0.2	0.73
Ash	73.0	62.4	50.8	4.2	0.70
Energy					
GE, kcal/kg	5,142	5,248	5,468	.	.
DE, kcal/kg	3,314	3,270	3,477	106	0.42
ME, kcal/kg	3,076	3,085	3,223	173	0.65
DE/GE, %	70.4	70.4	70.0	1.4	0.95
ME/DE, %	92.7	94.2	92.6	1.4	0.46
ME/GE, %	59.8	58.8	58.9	3.3	0.94

[1]The same DDGS source were used in two studies

[abc]Values within a row with different superscripts are different ($P < 0.05$).