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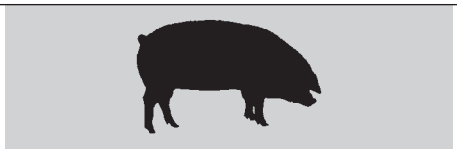

Concentration of digestible and metabolizable energy and digestibility of energy and nutrients by growing pigs in distillers dried grains with solubles produced in and around Illinois

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ABSTRACT

Illinois is one the major corn producing states in the nation, and much of the corn produced in Illinois is used to produce ethanol. In recent years, ethanol plants have been centrifuging solubles, and the resulting distillers dried grains with solubles (DDGS) contains less fat than conventional DDGS. Therefore, the purpose of this experiment was to determine if the concentration of DE and ME in DDGS produced in and around Illinois varies among plants. Twenty-four barrows (average initial BW: 28.1 ± 1.8 kg) were randomly allotted to 1 of 24 dietary treatments in a 24 × 8 Youden square design with 24 diets and 8 periods. Approximately 250 kg of DDGS was procured from 23 ethanol plants, and a corn diet and 23 corn–DDGS diets were formulated. Results indicated that only 3 of the 23 sources of DDGS could be categorized as conventional DDGS with more than 10% acid hydrolyzed ether extract, whereas the remaining 20 sources of DDGS contained between 5 and 10% acid hydrolyzed ether extract, thus categorizing these sources as low-oil DDGS. The concentration of DE in conventional DDGS was greater ($P < 0.05$) than in low-oil DDGS, and the concentration of ME tended ($P = 0.066$) to be greater in conventional DDGS than in low-oil DDGS. These observations indicate that almost all ethanol plants in and around Illinois remove some of the fat from the solubles, but this practice will reduce the energy value of the DDGS that is produced.

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INTRODUCTION

Illinois produces approximately 7% of all pigs and approximately 16.5% of the corn in the United States (USDA, 2015). Much of the corn is used for ethanol production, and the resulting distillers dried grains with solubles (**DDGS**) is fed to pigs in Illinois, but swine producers in Illinois may also procure DDGS from ethanol plants located close to the state line in the surrounding states. Conventional DDGS contains approximately 27% CP, 10% fat, 9% ADF, and 25% NDF (Stein and Shurson, 2009), and up to 45% DDGS may be included in diets fed to growing-finishing pigs without major reductions in pig growth performance (Cromwell et al.,

Table 1. Ingredient composition (%) of experimental diets, as-fed basis

	Diet	
Ingredient	Corn	DDGS[1]
Ground corn	97.80	57.80
DDGS	—	40.00
Ground limestone	1.35	1.35
Monocalcium phosphate	0.15	0.15
Sodium chloride	0.40	0.40
Vitamin-mineral premix[2]	0.30	0.30
Total	100.00	100.00

[1]DDGS = distillers dried grains with solubles.

[2]Provided the following per kilogram of complete diet: vitamin A as retinyl acetate, 11,136 IU; vitamin D_3 as cholecalciferol, 2,208 IU; vitamin E as DL-α tocopheryl acetate, 66 IU; vitamin K as menadione dimethylpyrimidinol bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.59 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin, 44.1 mg; folic acid, 1.59 mg; biotin, 0.44 mg; Cu as copper sulfate and copper chloride, 20 mg; Fe as ferrous sulfate, 126 mg; I as ethylenediamine dihydroiodide, 1.26 mg; Mn as manganese sulfate, 60.2 mg; Se as sodium selenite and selenium yeast, 0.3 mg; and Zn as zinc sulfate, 125.1 mg.

2011). However, different processing technologies of corn grain are used in the industry, which may result in production of DDGS with different concentrations of energy and nutrients (NRC, 2012). The concentration of DE and ME in conventional sources of DDGS is approximately 3,500 and 3,350 kcal/kg, respectively (Stein and Shurson, 2009), but it is possible that DE and ME differ among sources of DDGS produced using different processing technologies. In recent years, ethanol plants have extracted oil by centrifugation from solubles or from DDGS by solvent extraction using ethanol or hexane (Jacela et al., 2011; Rosentrater et al., 2012; Kerr et al., 2013). This type of processing results in reduced ether extract and possibly reduced concentrations of DE and ME (Kerr et al., 2013). If that is the case, swine producers may purchase DDGS that contains less energy than expected, which may result in inaccuracies in diet formulations. Ultimately, this may also result in poorer performance of pigs fed DDGS-containing diets, which may contribute to a reduced perception among swine producers of the value of DDGS. It was, therefore, the objective of this experiment to determine if the concentrations of DE and ME in DDGS produced in and around Illinois are in agreement with previously obtained values.

MATERIALS AND METHODS

Selection of Distillers Dried Grains with Solubles

Sources of DDGS were procured from 11 ethanol plants in Illinois, 4 ethanol plants in Indiana, 4 ethanol plants in Iowa, 2 ethanol plants in Missouri, and 2 ethanol plants in Wisconsin. Therefore, a total of 23 sources of DDGS were used. The ethanol plants that were not located in Illinois were located within 100 miles from the Illinois state line. Each sample of DDGS (approximately 250 kg) was clearly labeled on arrival at the University of Illinois and stored at approximately 15°C.

Animals, Housing, Experimental Design, and Diets

A total of 24 growing barrows (Genetiporc, Alexandria, MN) with an average initial BW of 28.1 ± 1.8 kg were used in this experiment. Pigs were randomly allotted to 1 of 24 dietary treatments in a 24 × 8 Youden square design with 24 diets and 8 periods. Pigs were placed in metabolism crates that were equipped with a feeder and a nipple drinker, slatted floors, a screen floor, and a urine tray. The crates allow for total, but separate, collection of urine and feces from each individual pig.

A total of 24 diets were formulated, and the basal diet was based on corn, minerals, and vitamins (Tables 1 and 2). Twenty-three additional diets were formulated by mixing corn and 40% of each source of DDGS. Vitamins and minerals were included in all diets to meet current requirements (NRC, 2012). An AA supplement was also formulated to contain 76, 16, and 8% of Lys, Thr, and Trp, respectively.

Feeding and Sample Collection

Diets were provided daily in 2 equal meals in the amount of approximately 90% of ad libitum intake (i.e., 197 kcal ME per $kg^{0.60}$; NRC, 2012). Pigs were allowed ad libitum access to water throughout the experiment. The initial 7 d were considered an adaptation period to the diet. The AA supplement was provided during the adaptation period at 25 g/d and fed in 2 equal portions that were mixed into the meal of each pig. Following the adaptation period, urine and feces were collected during the following 5 d according to standard procedures using the marker-to-marker approach (Adeola, 2001). Urine was collected once daily in urine buckets over a preservative of 50 mL of 3 *N* HCl, the weights of the collected urine were recorded, and 20% of the collected urine was stored at −20°C. Fecal samples were collected twice daily and stored at −20°C. At the conclusion of the experiment, urine samples were thawed and mixed within animal and diet, and subsamples were collected for analysis. Fecal samples were also thawed and mixed within animal and diet, weighed, mixed with water to create a homogenous slurry, weighed

Table 2. Analyzed nutrient composition of experimental diets, as-fed basis

		DDGS[1]			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[4]
DM, %	86.35	90.35	88.27	0.925	0.154
Ash, %	3.84	4.81	5.24	0.189	0.144
CP, %	8.23	16.76	17.24	0.376	0.406
ADF, %	3.34	7.17	7.10	0.416	0.918
NDF, %	8.45	16.08	16.42	0.478	0.643
GE, kcal/kg	3,857	4,133	4,060	19.737	0.023

[1]DDGS = distillers dried grains with solubles.

[2]Represents the mean of 3 diets containing DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 diets containing DDGS with >5 and <10% AEE.

[4]Comparison of the 2 categories of DDGS.

again, and subsampled. Each subsample was weighed and used for analysis.

Chemical Analysis

Fecal subsamples were dried in a forced-air oven and finely ground before analysis. Samples of all ingredients, diets, and feces were analyzed for DM and ash by oven drying at 135°C for 2 h (method 930.15; AOAC International, 2007) and dry ash at 600°C for 2 h and 45 min (method 942.05; AOAC International, 2007), respectively. Concentrations of CP were analyzed in samples of ingredients, diets, feces, and urine using a combustion procedure (method 990.03; AOAC International, 2007) on an Elementar Rapid N-cube protein/nitrogen apparatus (Elementar Americas Inc., Mt. Laurel, NJ). Aspartic acid was used as a calibration standard, and CP was calculated as N × 6.25. Ingredients, diets, feces, and urine were also analyzed for GE by peribolic bomb calorimetry (Model 6300, Parr Instruments, Moline, IL). Benzoic acid was used as the standard for calibration. Urine samples were prepared for GE analysis as previously outlined (Kim et al., 2009). All ingredients were analyzed for acid hydrolyzed ether extract (**AEE**; method 954.02, AOAC International, 2006), AA [method 982.30 E (a, b, c); AOAC International, 2007], Ca, P, Cu, Fe, Mg, Mn, K, Se, Na, S, Zn, and Cl (method 975.03; AOAC International, 2007), and starch and lignin [method 76–13; AACC International, 2000; method 973.18 (A-D); AOAC International, 2006]. Diets and ingredients were also analyzed for concentrations of ADF and NDF using method 973.18 (AOAC International, 2007) and that of Holst (1973), respectively. The bulk density (Cromwell et al., 2000) and particle size (ASABE, 2008) of corn and each source of DDGS were determined.

Calculations and Data Analysis

Hemicellulose and cellulose were calculated using published equations (NRC, 2012). The apparent total-tract digestibility (**ATTD**) of energy, N, DM, and OM, and the concentration of DE and ME in each diet were calculated (Adeola, 2001). The concentrations of DE and ME in the corn diet were then divided by the inclusion rate of corn in that diet to calculate the concentration of DE and ME in corn. These values were used to calculate the contribution of corn to the corn–DDGS diets, and the digestibility of energy and nutrients and the concentration of DE and ME in each source of DDGS were calculated by difference (Adeola, 2001). These procedures were also used to determine N balance for each diet and ingredient.

Following the analysis for AEE, the 23 sources were categorized according to the NRC (2012) as "conventional DDGS," containing more than 10% AEE, or "low-oil DDGS," containing between 5 and 10% AEE.

Data were analyzed using the MIXED procedure in SAS (SAS Institute Inc., Cary, NC). The source of DDGS was the experimental unit for analyses comparing the concentrations of GE, DM, and nutrients between conventional DDGS and low-oil DDGS, and the model to analyze nutrient composition included the category of DDGS as the fixed effect and source of DDGS as the random effect. Pig was the experimental unit for all other analyses, with the model including diet as fixed effect and period as random effect. Outliers were tested using the UNIVARIATE procedure. One outlier was removed in calculations of ME and N retention, and one outlier was removed for calculation of ATTD of N. The LSMeans procedure of SAS was used to calculate the least squares means. If differences were detected, the PDIFF option with the Tukey's adjustment was used to separate the means. An α level of 0.05 was used to assess significance among means, and a *P*-value between 0.05 and 0.10 was considered a trend.

RESULTS AND DISCUSSION

Composition of DDGS

Conventional DDGS contains >10% fat (Stein and Shurson, 2009; NRC, 2012); however, in the past few years, ethanol producers have been centrifuging solubles to extract oil to sell to the biodiesel industry (Winkler-Moser and Breyer, 2011; Kerr et al., 2013). The resulting DDGS typically contains between 5 and 10% AEE and is categorized as low-oil DDGS (NRC, 2012). According to this definition, 3 of the sources of DDGS used in this

experiment were categorized as conventional DDGS, whereas the remaining 20 sources were low-oil DDGS. This observation indicates that oil was extracted from the solubles in the production of most of the sources of DDGS that were used.

Distillers dried grains with solubles is used in swine diets because of a relatively high concentration of AA and energy (Stein and Shurson, 2009). When DDGS undergoes the drying process, the high temperature and concentration of moisture makes DDGS susceptible to the Maillard reactions, which can lead to reduced AA concentration and digestibility. Especially, Lys concentration and digestibility may be reduced as a result of the Maillard reaction (Pahm et al., 2008; Almeida et al., 2013). It is recommended that DDGS be used in swine diets only if the Lys:CP ratio is greater than 2.80% (Stein, 2007) because a Lys:CP ratio less than 2.80% indicates that the DDGS has been heat damaged. The average Lys:CP ratio was 3.19% in conventional DDGS used in this experiment and 3.22% in low-oil DDGS, with the least value being 2.87%. These values indicate that all sources of DDGS used in this experiment were not heat damaged.

The concentration of DM was greater ($P < 0.05$) in conventional DDGS than in low-oil DDGS (92.05 vs. 90.10%), but no differences in ash and CP were observed between the 2 categories of DDGS (Table 3). Concentrations of CP in both categories of DDGS were within the range of published values (Pedersen et al., 2007; Jacela et al., 2011; NRC, 2012), but the average concentration of ash in low-oil DDGS was greater than reported values (Jacela et al., 2011; Kim et al., 2012a; NRC, 2012). As expected, the concentration of AEE in conventional DDGS (10.49%) was greater ($P < 0.05$) than in low-oil DDGS (7.54%), and GE also was greater ($P < 0.05$) in conventional DDGS than in low-oil DDGS (4,781 vs. 4,522 kcal/kg). In contrast, bulk density and particle size were not different between the 2 categories of DDGS. Anderson et al. (2012) and Kerr et al. (2013) reported that there is a wide range in DDGS bulk density and particle size, which is consistent with observations in this experiment, but the average bulk density and particle size for both categories of DDGS were close to expected values.

There were no differences in concentrations of any AA between conventional DDGS and low-oil DDGS (Table 4), and the values obtained in this experiment are within the range of values previously published (Stein and Shurson, 2009; NRC, 2012). There were also no differences between conventional and low-oil DDGS in concentration of ADF, NDF, lignin, hemicellulose, and cellulose (Table 5). However, conventional DDGS contained more ($P < 0.05$) starch (3.19%) than low-oil DDGS (1.05%), but both values are less than published values for starch in DDGS (Stein et al., 2006; Pedersen et al., 2007; Gutierrez et al., 2014), which indicates that there is variability in the efficiency of starch fermentation among ethanol plants. However, it appears that most ethanol plants, and specifically those that have installed oil skimming equipment, are very efficient in converting starch to ethanol, and the residual starch left in DDGS is less than that observed in DDGS that was produced around 10 yr ago. The average GE in the 3 sources of conventional DDGS was close to published values, but the average GE in the low-oil DDGS was less than published data (Pedersen et al., 2007; Kim et al., 2012a; NRC, 2012). The reason for the reduced GE in the low-oil DDGS may be that sources of DDGS in this category had not only a low amount of AEE but also a very low concentration of starch.

The concentration of Cu was greater ($P < 0.05$) in conventional DDGS than in low-oil DDGS, whereas the concentration of Na was greater ($P < 0.05$) in low-oil DDGS than in conventional DDGS (Table 6). There was also a trend ($P = 0.068$) for a

Table 3. Proximate analysis, GE, bulk density, and particle size of corn and 23 sources of distillers dried grains with solubles (DDGS), as-fed basis

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
DM, %	88.58	92.05	90.10	0.357	0.002
Ash, %	1.28	5.31	6.08	0.308	0.117
CP, %	8.57	29.09	30.07	0.740	0.393
AEE, %	3.79	10.49	7.54	0.330	<0.001
GE, kcal/kg	3,938	4,781	4,522	44.093	<0.001
Bulk density, g/L	611	488	466	18.847	0.426
Particle size, µm	885	674	577	78.149	0.390

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 sources of DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 sources of DDGS with >5 and <10% AEE.

Table 4. Concentration of AA in corn and 23 sources of distillers dried grains with solubles (DDGS), as-fed basis

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
Indispensable AA, %					
Arg	0.41	1.25	1.29	0.041	0.556
His	0.25	0.77	0.81	0.018	0.135
Ile	0.29	1.11	1.15	0.033	0.375
Leu	1.00	3.27	3.41	0.115	0.407
Lys	0.31	0.93	0.97	0.038	0.481
Met	0.17	0.54	0.55	0.020	0.790
Phe	0.41	1.41	1.47	0.044	0.349
Thr	0.31	1.08	1.11	0.029	0.407
Trp	0.06	0.16	0.18	0.007	0.175
Val	0.39	0.136	1.42	0.038	0.353
Mean	3.60	1.19	1.23	0.034	0.351
Dispensable AA, %					
Ala	0.62	1.93	2.00	0.063	0.454
Asp	0.56	1.75	1.80	0.051	0.511
Cys	0.18	0.51	0.54	0.019	0.423
Glu	1.52	3.89	4.01	0.196	0.678
Gly	0.35	1.18	1.23	0.043	0.429
Pro	0.73	2.10	2.20	0.072	0.312
Ser	0.40	1.27	1.33	0.042	0.328
Mean	3.96	1.81	1.87	0.063	0.457
Total AA	7.17	26.01	27.01	0.768	0.364
Lys:CP ratio,[4] %	3.62	3.19	3.22	0.092	0.825

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 sources of DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 sources of DDGS with >5 and <10% AEE.

[4]The Lys:CP ratio was calculated by expressing the concentration of Lys in each sample as a percentage of the concentration of CP (Stein et al., 2009).

greater concentration of K in low-oil DDGS than in conventional DDGS, but for all other minerals, no difference between conventional DDGS and low-oil DDGS was observed. However, concentrations of Ca, Na, Mg, and Mn in both categories of DDGS were less than values reported by the NRC (2012), but concentrations of P, K, S, Zn, Se, and Cu were greater than reported values (NRC, 2012). The concentration of S in all sources of DDGS ranged from 0.37 to 1.20% (data not shown), which is in agreement with reported data (Kerr et al., 2008; Kim et al., 2012b), and indicates that some ethanol plants may use sulfuric acid to control the fermentation process, whereas other plants do not use sulfuric acid and therefore produce DDGS containing less S. The nutrient composition of corn was in agreement with the values reported by the NRC (2012), except for the concentrations of ADF, lignin, starch, and Cu, which were all greater than values reported by NRC (2012).

Regardless of the category of DDGS, the sum of the analyzed concentrations of CP, AEE, ash, starch, and NDF added to between 85 and 90% of the DM, which is in agreement with most previous analyses of the composition of DDGS (Stein and Shurson, 2009; NRC, 2012). This observation indicates that as is the case for many coproducts, a proportion of the DDGS cannot be accounted for by traditional proximate analyses. As a consequence, and assuming that the unaccounted part of the ingredient contributes DE and ME to DDGS, it may not always be accurate to estimate DE and ME in DDGS from proximate components as has sometimes been attempted (Pedersen et al., 2007; Anderson et al., 2012). Regression equations to estimate DE and ME from analyzed composition were, therefore, not developed from the data obtained in this experiment.

Digestibility of Nutrients and Concentration of DE and ME

The DE and ME and the ATTD of DM were greater ($P < 0.05$) in diets containing conventional DDGS than in diets containing low-oil DDGS (Table 7). However, the amount of N absorbed per day and the ATTD of N were greater ($P < 0.05$) in diets containing low-oil DDGS than in diets containing conventional DDGS, and there were tendencies for N intake (g/d) and N retention (%) to be greater in diets containing low-oil DDGS than in diets containing conventional DDGS ($P = 0.057$ and 0.090, respectively). In contrast, there was a tendency ($P = 0.051$) for the ATTD of OM to be greater in diets containing conventional DDGS than in diets containing low-oil DDGS.

The DE and ME (as-fed basis) and the DE (DM basis) were greater ($P < 0.05$) in conventional DDGS than in low-oil DDGS, and there was a tendency ($P = 0.066$) for the ME in conventional DDGS to be greater than in low-oil DDGS (Table 8). In contrast, N absorbed and ATTD of N were greater ($P < 0.05$) in low-oil DDGS than in conventional DDGS, and N intake (g/d) tended ($P = 0.057$) to be greater in low-oil DDGS than in conventional DDGS.

The DE and ME of corn were 3,842 and 3,673 of kcal/kg of DM, which is in agreement with published values (NRC, 2012) but is slightly less than values reported by Pedersen et al.

Table 5. Carbohydrate concentration in corn and 23 sources of distillers dried grains with solubles (DDGS), as-fed basis

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
ADF, %	4.31	13.94	13.53	1.094	0.793
NDF, %	9.08	27.58	28.55	1.276	0.595
Lignin, %	1.07	4.84	3.78	0.588	0.217
Hemicellulose,[4] %	4.77	13.64	15.02	1.004	0.341
Cellulose,[5] %	3.24	9.10	9.75	0.610	0.461
Starch, %	66.83	3.19[a]	1.05[b]	0.674	0.035

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 sources of DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 sources of DDGS with >5 and <10% AEE.

[4]Calculated as hemicellulose = NDF − ADF (NRC, 2012).

[5]Calculated as cellulose = ADF − lignin (NRC, 2012).

(2007). However, the corn used in this present experiment contained more ADF and lignin than in previous experiments and had a particle size of 885 μm, which results in lower values for DE and ME than if the particle size were less (Wondra et al., 1995; Rojas and Stein, 2015). The DE and ME in the corn used in this experiment are also greater than the values reported by Liu et al. (2012), who also used corn with a particle size above 800 μm. The ATTD of GE in corn was slightly less than reported values (Pedersen et al., 2007; Stein et al., 2009; Kerr et al., 2013), which may be a consequence of the particle size in corn used in this experiment being greater than for corn used in previous experiments. The ATTD of N in corn was slightly less than reported values (Pedersen et al., 2007; Liu et al., 2012; Kerr et al., 2013).

Table 6. Mineral composition of corn and 23 sources of distillers dried grains with solubles (DDGS), as-fed basis

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
Macrominerals, %					
Calcium	0.01	0.05	0.03	0.010	0.143
Phosphorous	0.27	0.74	0.80	0.029	0.126
Sodium	ND[4]	0.09	0.21	0.031	0.011
Potassium	0.34	0.98	1.06	0.031	0.068
Magnesium	0.10	0.27	0.29	0.013	0.234
Sulfur	0.12	0.69	0.71	0.093	0.887
Microminerals, mg/kg					
Iron	18.4	87.9	78.9	7.232	0.391
Zinc	20.5	70.9	63.3	4.767	0.270
Molybdenum	0.3	0.8	0.9	0.158	0.826
Manganese	4.7	16.5	15.6	1.830	0.750
Copper	1.7	8.5	6.4	0.627	0.026

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 sources of DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 sources of DDGS with >5 and <10% AEE.

[4]ND = not detectable.

The average DE and ME in conventional DDGS were close to expected values (NRC, 2012), but values for low-oil DDGS were less than values reported by Pedersen et al. (2007), Anderson et al. (2012), and Liu et al. (2012). However, the DE in low-oil DDGS was in agreement with values reported by Kerr et al. (2013), and the DE and ME calculated for low-oil DDGS in this experiment were greater than values for DE and ME in deoiled DDGS (Jacela et al., 2011). These observations are likely a result of the differences in AEE among conventional, low-oil, and deoiled DDGS.

For every 25-μm decrease in the particle size of DDGS, ME is increased by 13.46 kcal/kg of DM (Liu et al., 2012). The variability in DDGS particle size that was observed in this experiment may, therefore, have contributed to the variability in ME both in conventional DDGS and low-oil DDGS. The average ATTD of GE (68.8% in conventional DDGS and 70.1% in low-oil DDGS) was in agreement with the range of ATTD of GE in DDGS reported by Stein et al. (2006) but less than the range of ATTD of GE reported by Kerr et al. (2013) and Stein et al. (2009). The N retained in pigs fed corn was slightly greater than the value reported by Pedersen et al. (2007); however, the concentration of CP in corn used in this experiment was greater than the CP in corn used by Pedersen et al. (2007), which may account for this difference. The N retained from pigs fed DDGS was in agreement with reported values (Pedersen et al., 2007). The average ATTD of N (79.4 and 81.5% in conventional and low-oil DDGS, respectively) was in agreement with published values (Pedersen et al., 2007; Stein et al., 2009; Liu et al., 2012; Kerr et al., 2013).

Table 7. Concentrations of DE and ME, daily N balance, and apparent total-tract digestibility (ATTD) of GE, N, DM, and OM in experimental diets containing corn or distillers dried grains with solubles (DDGS), as-fed basis

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
DE, kcal/kg	3,329	3,281	3,214	20.829	<0.001
ME, kcal/kg	3,182	3,089	3,014	25.271	<0.001
N intake, g/d	25.2	51.8	53.2	5.107	0.057
N in feces, g/d	5.8	10.7	10.3	0.795	0.145
N in urine, g/d	8.6	20.7	21.4	3.521	0.675
N absorbed, g/d	19.4	41.1	42.9	4.370	0.016
N retained, g/d	9.3	20.4	22.1	2.345	0.128
N retention,[4] %	40.9	39.3	42.6	3.088	0.090
ATTD of GE, %	86.3	79.3	79.2	0.491	0.680
ATTD of N, %	77.1	78.9	80.3	0.791	0.016
ATTD of DM, %	88.6	82.4	81.6	0.457	0.034
ATTD of OM, %	89.7	81.6	80.8	0.401	0.051

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 diets containing DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 diets containing DDGS with >5 and <10% AEE.

[4]Calculated as N retention = (N retained/N intake) × 100.

Table 8. Concentration of DE and ME, daily N balance, and apparent total-tract digestibility (ATTD) of GE and N in corn and distillers dried grains with solubles (DDGS)

		DDGS			
Item	Corn	Conventional DDGS[2]	Low-oil DDGS[3]	SEM	*P*-value[1]
DE, kcal/kg, as fed	3,403	3,285	3,117	52.071	<0.001
DE, kcal/kg of DM	3,842	3,567	3,460	57.853	0.041
ME, kcal/kg, as fed	3,254	3,020	2,844	58.643	0.003
ME, kcal/kg of DM	3,673	3,278	3,157	65.157	0.066
N intake, g/d	25.8	36.9	38.3	5.107	0.057
N in feces, g/d	5.9	7.3	6.8	0.795	0.145
N in urine, g/d	8.8	13.8	14.3	3.577	0.632
N absorbed, g/d	19.9	29.6	31.4	3.069	0.016
N retained, g/d	9.5	15.9	17.4	2.443	0.186
N retention,[4] %	40.9	40.9	45.0	2.337	0.105
ATTD of GE, %	86.4	68.8	70.1	1.181	0.331
ATTD of N, %	77.1	79.4	81.5	1.043	0.012

[1]Comparison of the 2 categories of DDGS.

[2]Represents the mean of 3 sources of DDGS with >10% acid hydrolyzed ether extract (AEE).

[3]Represents the mean of 20 sources of DDGS with >5 and <10% AEE.

[4]Calculated as N retention = (N retained/N intake) × 100.

IMPLICATIONS

The DDGS procured from ethanol plants in Illinois and surrounding states varied in nutrient composition, nutrient digestibility, and DE and ME concentration. The variability may have been caused by the amount of solubles added to wet grains before drying or the centrifugation of solubles for oil extraction.

Producers in and around Illinois should be aware of the composition of the DDGS they purchase because this may influence the nutritional value of the ingredient. Indeed, the DE and ME in conventional DDGS that contains more than 10% AEE is greater than in low-oil DDGS, which contains between 5 and 10% AEE. However, it appears that DDGS produced within the last few years, regardless of the concentration of AEE, contains more Lys and is less likely to be heat damaged than DDGS produced around 10 yr ago.

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