Nutrient database for distiller's dried grains with solubles produced from new ethanol plants in Minnesota and South Dakota

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ABSTRACT: A study was conducted to evaluate the nutrient content and variability of distiller's dried grains with solubles (DDGS) originating from new (less than 5 yr old) ethanol plants in Minnesota and South Dakota. Ten plants (8 MN, 2 SD) participated in the study, submitting a total of 118 samples. Samples were collected every 2 mo from ten ethanol plants in the Minnesota-South Dakota (MNSD) region from 1997 to 1999 and were analyzed for amino acid levels, DM, CP, crude fiber, crude fat, ash, ADF, NDF, Ca, P, K, Mg, S, Na, Zn, Mn, Cu, and Fe analysis. Digestible energy (DE), ME, and NFE levels were also calculated. Means (dry-matter basis) and coefficients of variation for each nutrient among all plants during 1997 to 1999 were DM (88.9%, 1.7%), CP (30.2%, 6.4%), crude fat (10.9%, 7.8%), crude fiber (8.8%, 8.7%), ash (5.8%, 14.7%), NFE (45.5%, 6.1%), ADF (16.2%, 28.4%), NDF (42.1%, 14.3%), calculated DE (3,990 kcal/kg, 3.24%), calculated ME (3,749 kcal/kg, 3.28%), Arg (1.20%, 9.1%), His (0.76%, 7.8%), Ile (1.12%, 8.7%), Leu (3.55%, 6.4%), Lys (0.85%, 17.3%), Met (0.55%, 13.6%), Phe (1.47%, 6.6%), Thr (1.13%, 6.4%), Trp (0.25%, 6.7%), Val (1.50%, 7.2%), Ca (0.06%, 57.2%), and P (0.89%, 11.7%), respectively. Among the amino acids analyzed, Lys was the most variable (CV = 17.3%), followed by Met (CV = 13.6%). Nutrient levels of MNSD DDGS were higher in crude fat, NDF, DE, ME, P, Lys, Met, and Thr and lower for DM, ADF, and Ca than NRC (1998) values. Nutrient values differed between years for ash, DE, Mn, Zn, Cys ($P < 0.10$), Fat, TDN, ME, Met, Ile ($P < 0.05$), Ca, P, K, Mg, and Cu ($P < 0.01$). These results suggest that gross energy; P; and total Lys, Met, and Thr levels are higher in DDGS from MNSD ethanol plants compared to published values and chemical analysis values of a DDGS sample obtained from an older Midwestern plant.

Key Words: Distiller's Grains, Distiller's Solubles, Nutrients

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Introduction

Corn distiller's dried grains with solubles (**DDGS**) is a by-product of the fuel ethanol industry. During the production of alcohol, starch is removed from the grain and converted to alcohol and carbon dioxide. As a result of starch removal, the concentration of the remaining nutrients in the grain increases approximately threefold.

Reliable values for the nutrient content of feed ingredients are essential to swine nutritionists in order to create more precise diet formulations. Because DDGS are a by-product of a process designed for ethanol production, factors such as selection of grains, type of fermentation (continuous vs batch), and drying temperature and duration (Carpenter, 1970; Olentine, 1986) can influence the nutritional and physical properties of DDGS. Research demonstrating product variability among DDGS sources (Carpenter, 1970; Cromwell and Stahly, 1986; Cromwell et al., 1993) and relatively low lysine levels relative to other amino acids (Wahlstrom et al., 1970; Cromwell et al., 1983) have discouraged nutritionists from using substantial amounts of DDGS in swine diets.

Very little research has been conducted on distiller's by-products within the last 15 yr, although the process used to produce ethanol has changed during that time. The current published DDGS values reflect the composition of product produced nearly 20 yr ago. Research should be conducted using DDGS from new ethanol plants in order to have more precise estimates of the nutrient composition of DDGS.

The objectives of this study were to identify nutrient values of DDGS produced in 10 new ethanol plants (less than 5 yr old) in the Minnesota-South Dakota (**MNSD**) region, determine nutrient variability among and within plants, and compare MNSD DDGS to reference values (NRC, 1998; Feedstuffs Reference Issue, 1999; Heartland Lysine, Inc., 1998) and DDGS pro-

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duced in an older midwestern plant (**OMP**). Year-to-year differences were also examined in this study.

Materials and Methods

General

Samples of DDGS were collected every 2 mo during 1997 (n = 38), 1998 (n = 50), and 1999 (n = 30) from ethanol plants in the MNSD region. Eight plants submitted 12 samples each, and two plants submitted 11 samples each for a total of 118 samples. Additionally, four samples were submitted from an OMP. All samples were sent to the Swine Nutrition Laboratory, Department of Animal Science, University of Minnesota. Subsamples were then sent to University of Missouri (Columbia, MO) for amino acid analysis using AOAC Official Method 982.30 E (a,b,c) and Iowa Testing Laboratory Inc. (Eagle Grove, IA) for proximate and mineral analyses. Samples were submitted to analytical laboratories for proximate analysis, and mineral and amino acid analysis at various time periods throughout the duration of the study beginning on 11/30/98 and ending on 2/22/00. Digestible and metabolizable energy values were calculated using the following NRC (1998) formulas from Noblet and Perez (1993):

$$\text{DE kcal/kg} = 4151 - (122 \times \%\ \text{Ash}) + (23 \times \%\ \text{CP}) + (38 \times \%\ \text{EE}) - (64 \times \text{Crude fiber})$$

$$\text{ME kcal/kg} = \text{DE} \times (1.003 - (0.0021 \times \%\ \text{CP}))$$

A DDGS sample from an OMP considered typical for the industry was also collected for comparison purposes. Four subsamples of the OMP DDGS were submitted to the same laboratories as the MNSD DDGS for proximate, mineral, and amino acid analysis.

Statistics

Data were entered in a Microsoft Excel (Microsoft Corp., Redmond, WA) spreadsheet and descriptive statistics were calculated to determine the mean, standard error, standard deviation, sample variance, and coefficient of variation for each plant. The GLM procedure of SAS (SAS Inst. Inc., Cary, NC) was used to determine year-to-year differences between samples and to compare the DDGS samples collected from MNSD ethanol plants to DDGS collected from OMP.

Nutrient values of the MNSD DDGS were compared to published values in NRC (1998), Heartland Lysine Amino Acid Database (1998), and Feedstuffs Reference Issue (1999), as well as the sample of DDGS collected from an OMP.

Results and Discussion

In general, variation in nutrient levels between and within plants was low with coefficients of variation less than 5% for dry matter, calculated DE, and calculated ME values and less than 10% for crude protein, crude fat, crude fiber, and NFE. Coefficients of variation for amino acids were generally less than 10%. This indicates consistency within and uniformity among Minnesota and South Dakota (MNSD) ethanol plants. However, there was higher variability in total lysine and methionine levels among sources (CV = 17.3 and 13.6%, for Lys and Met, respectively). Mineral levels were highly variable, with coefficients of variation ranging from 11.7% for phosphorus to 80.4% for zinc. The nutrient content of the soil can affect the concentration of some nutrients in corn, and ultimately DDGS. However, measuring soil fertility and its correlation with corn nutrient levels used to produce DDGS are beyond the scope of this study. The location of the ethanol plants used in this study have been clearly defined and only corn produced near these plant locations is used to produce the DDGS reported in this study. The ratio of grains and solubles used to manufacture DDGS will have more influence on final nutrient content of DDGS than soil fertility differences. Most of the variation in the nutrient content of DDGS was likely a result of corn crop used, percent of dried solubles added back to distiller's dried grains, and completeness or duration of the fermentation process, which affects the degree of starch removal.

Composite means for each nutrient (dry matter basis) in MNSD DDGS, as well as nutrient composition of DDGS from individual plants are shown in Table 1. Dry matter content of the MNSD DDGS samples ranged from 88.4% to 90.2%, with an average dry matter of 88.9%. Average nutrient content (dry matter basis) of the MNSD DDGS for crude fat, crude fiber, ADF, NDF, and crude protein were 10.9, 8.8, 16.2, 44.5, and 30.2%, respectively. Average calculated DE and ME values (dry matter basis) for the MNSD DDGS were 3,990 and 3,749 kcal/kg, respectively.

Average dry matter content of MNSD DDGS was slightly less than the values from three commonly used ingredient nutrient value references (NRC, 1998; Heartland Lysine, 1998; Feedstuffs Reference Issue, 1999) and slightly more than the dry matter content of DDGS from the OMP. Dry matter content of 88% should be acceptable for maintaining product quality during storage. Excessive drying can contribute to reduced amino acid digestibility and increased cost in DDGS production.

Average crude protein levels in MNSD DDGS were higher than crude protein values in NRC (1998), Heartland Lysine (1998), and Feedstuffs Reference Issue (1999) and in the DDGS from the OMP. High crude protein values for the MNSD DDGS suggest that perhaps the fermentation technology used by the MNSD ethanol plants may result in more complete starch removal. However, the protein quality of DDGS is poor relative to the amino acid requirements of the pig. Because corn is the primary grain used in ethanol production, the resulting DDGS has a similar, inferior amino acid profile. Lysine levels are low relative to

Table 1. Proximate analysis of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older midwestern ethanol plant (OMP) and published reference values[a]

Sample origin	No. of samples	DM (%)	CP (%)	Fat (%)	Fiber (%)	Ash (%)	NFE (%)	ADF (%)	NDF (%)	DE[b] (kcal/kg)	ME[b] (kcal/kg)
MN-SD											
Aberdeen	12	87.4 (1.7)	30.8 (10.2)	10.2 (10.5)	8.9 (11.1)	6.3 (14.8)	43.8 (8.8)	14.2 (8.0)	46.2 (10.0)	3912 (4.2)	3671 (4.3)
Bingham Lk	12	90.2 (1.0)	30.9 (7.6)	10.7 (6.1)	9.1 (6.6)	6.4 (15.1)	43.8 (8.4)	18.1 (7.5)	44.4 (5.0)	4084 (2.3)	3838 (2.2)
Benson	12	88.4 (1.0)	30.1 (2.7)	11.2 (5.0)	8.3 (5.6)	5.4 (11.4)	45.0 (2.9)	14.8 (51.8)	37.0 (19.7)	3879 (5.1)	3639 (5.0)
Claremont	12	89.1 (1.3)	31.4 (2.1)	11.4 (5.5)	9.2 (5.9)	5.6 (8.8)	42.4 (3.2)	13.8 (—)[d]	40.5 (4.9)	4030 (1.5)	3776 (1.5)
Luverne	12	87.2 (1.1)	29.8 (3.3)	11.7 (7.4)	8.3 (8.8)	5.8 (11.6)	44.9 (3.9)	16.0 (55.8)	36.8 (20.6)	4023 (3.3)	3788 (3.4)
Morris	12	90.0 (2.0)	30.7 (6.8)	10.2 (9.1)	8.8 (9.3)	5.5 (16.7)	44.8 (7.2)	15.8 (8.4)	44.5 (4.3)	4013 (2.6)	3766 (2.6)
Preston	11	88.7 (1.5)	28.7 (5.7)	11.4 (7.0)	8.4 (8.9)	6.7 (7.4)	44.9 (4.9)	16.3 (54.2)	36.7 (23.1)	3890 (1.5)	3667 (1.7)
Scotland	11	89.8 (1.4)	31.6 (4.9)	10.8 (4.4)	9.7 (5.2)	5.7 (16.3)	42.2 (5.3)	18.5 (10.1)	49.1 (3.1)	3974 (2.5)	3720 (2.8)
Winnebago	12	90.0 (0.6)	28.7 (4.1)	10.7 (5.9)	8.3 (5.7)	5.4 (12.5)	46.9 (2.8)	15.4 (11.2)	42.8 (3.7)	4034 (2.6)	3803 (2.4)
Winthrop	12	88.7 (0.8)	29.5 (3.3)	10.8 (5.5)	8.7 (4.3)	5.2 (7.6)	45.8 (3.8)	17.1 (6.6)	41.9 (2.4)	4050 (1.2)	3811 (1.1)
1997 to 99	118	88.9 (1.7)	30.2 (6.4)	10.9 (7.8)	8.8 (8.7)	5.8 (14.7)	44.5 (6.1)	16.2 (28.4)	42.1 (14.3)	3990 (3.2)	3749 (3.3)
OMP DDGS	4	88.3 (0.9)	28.1 (2.4)	8.2 (12.6)	7.1 (4.2)	6.3 (17.5)	50.3 (5.9)	16.7 (—)[d]	35.4 (1.8)	3879 (2.6)	3661 (2.7)
Reference[c]											
NRC		93.0	29.8	9.0				17.5	37.2	3449	3038
HL		90.8	28.5								
FRI		93.0	29.0	8.6	9.1	4.8					3848

[a]Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.
[b]DE = 4151 − (122 × % Ash) + (23 × % CP) + (38 × % EE) − (64 × % crude fiber); ME = DE × [1.003 − (0.0021 × % CP)].
[c]References are: NRC, 1998. (NRC) Heartland Lysine, Inc. 1998. (HL), and Feedstuffs Reference Issue, 1999. (FRI)
[d]Only 1 sample analyzed.

crude protein in DDGS. As a result, feeding DDGS to swine will increase nitrogen excretion and can potentially increase ammonia emissions from the slurry. Additionally, increased nitrogen excretion demands metabolic energy for nitrogen removal, leaving less energy available to the animal for productive purposes. However, excess nitrogen resulting from the addition of DDGS to swine diets can be minimized by reducing dietary crude protein levels and supplementing with synthetic amino acids.

Average crude fat content in the MNSD DDGS was 10.9%, which is higher than 9.0% listed in NRC (1998) and 8.6% in Feedstuffs Reference Issue (1999). Crude fat content in OMP DDGS (8.2%) was also lower than MNSD DDGS. This high crude fat level in MNSD DDGS contributes to higher calculated DE and ME values for swine (3,990 and 3,749 kcal/kg, respectively) compared to DE and ME values in NRC (1998) (3,441 and 3,032 kcal/kg, respectively). Maximum energy intake is essential for maximizing pig performance in all production phases except during the gestation and late finishing phases. Consequently, the higher crude fat content of DDGS from MNSD compared to DDGS from the OMP results in improved nutritional value and is an advantage to the pig. Higher crude fat content in the MNSD DDGS contributes to higher DE and ME values and helps negate the energy dilution effect of the high fiber content in the DDGS. These values suggest that the energy value of MNSD DDGS is equal to corn and should not be a limiting factor in pig performance.

Additionally, ADF in MNSD DDGS was slightly less and NDF was slightly more than NRC (1998) levels. Since the difference between ADF and NDF is the amount of hemicellulose in the feed, the amount of hemicellulose in MNSD DDGS appears to be higher than normally believed. Since hemicellulose is slightly more digestible than the ADF fraction, this may provide a slight advantage in DE and ME for MNSD DDGS compared to published values.

Total ash content of the MNSD DDGS (5.8%) was slightly lower than OMP DDGS (6.3%) but slightly more than the value (4.8%) in Feedstuffs Reference Issue (1999). Since a high ash content reduces concentration of energy and amino acids, this may be an advantage of DDGS from MNSD compared to DDGS from OMP.

Of the ten essential amino acids analyzed in DDGS, lysine was the most variable (CV = 17.3%), with CV ranging from 2.9% to 25.7% (Table 2). Cromwell et al. (1993) also found lysine to be the most variable of the eleven amino acids measured. Precise diet formulations require predictability of lysine levels in DDGS. Therefore, the CV for each plant and each nutrient have been calculated and are included on Tables 1, 2, and 3 to aid nutritionists in using the by-product from each plant most effectively. Average lysine content in DDGS from MNSD is 0.85%, ranging from 0.72% to 1.02%. Average lysine levels for MNSD DDGS were higher than those published in NRC (1998) and Feedstuffs Reference Issue (1999), but similar to Heartland Lysine (1998) values (0.67, 0.65, and 0.81%, respectively).

Variability in methionine level among MNSD plants was the second highest (CV = 13.6%) of all amino acids analyzed. Methionine values ranged from 0.49% to 0.69% with an average methionine value of 0.55% for the MNSD DDGS. This is similar to the value of 0.54% listed in NRC (1998) but lower than the values in Feedstuffs Reference Issue (1999) and Heartland Lysine (1998) (0.65 and 0.63%, respectively).

Average tryptophan and threonine values were 0.25 and 1.13 %, respectively. Tryptophan values were within the range of published values (0.20 to 0.27%) and threonine values were higher than NRC (1998) and Feedstuffs Reference Issue (1999) values (1.01 and 1.02%, respectively), but similar to the Heartland Lysine (1998) value (1.11%).

Arginine (1.20%), histidine (0.76%), and phenylalanine (1.47%) values in the DDGS from MNSD ethanol plants were similar to the values in NRC (1998) (1.22, 0.74, and 1.44%, respectively) and Heartland Lysine (1998) (1.21, 0.75, and 1.43%, respectively) but appeared higher than the values in Feedstuffs Reference Issue (1999) (1.08, 0.65, and 1.29%, respectively). Isoleucine (1.12%) values from the MNSD DDGS were similar to NRC (1998) (1.11%) but appear slightly higher than the values in Heartland Lysine (1998) and Feedstuffs Reference Issue (1999) (1.09 and 1.08%, respectively). Leucine (3.55%) and valine (1.50%) values from MNSD DDGS appear higher than NRC (1998) (2.76 and 1.40%, respectively), Heartland Lysine (1998) (3.27 and 1.43%, respectively) and Feedstuffs Reference Issue (1999) (2.90 and 1.43%, respectively).

All 11 amino acids were higher in MNSD DDGS than the DDGS sample from the OMP evaluated in this study. This potentially makes MNSD DDGS a more valuable amino acid source than other DDGS sources, since less lysine supplementation would be needed to meet the desired lysine level in the diet. However, the variability in lysine and methionine levels among plants is of some concern because precise diet formulations require predictability of amino acid levels in MNSD DDGS. Because variability does exist between plants, nutritionists need to become familiar with nutrient levels and variability among and within individual plants before selecting a DDGS source.

Composite means for minerals (dry matter basis) in MNSD DDGS, as well as the mineral composition of DDGS from individual plants, are shown in Table 3. Levels of Ca, K, Mg, S, Na, Zn, Mn, Cu, and Fe in MNSD DDGS are of minor interest due to their low cost and relatively low concentrations, but were measured in order to develop a more complete nutrient profile of DDGS from MNSD ethanol plants.

Average phosphorus level of DDGS produced in Minnesota-South Dakota ethanol plants (0.89%) was

Table 2. Essential amino acid levels of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older midwestern plant (OMP) and published reference values[a]

Sample origin	No. of samples	Arg (%)	His (%)	Ile (%)	Leu (%)	Lys (%)	Met (%)	Phe (%)	Thr (%)	Trp (%)	Val (%)
MN-SD											
Aberdeen	12	1.31 (6.2)	0.82 (5.3)	1.14 (7.5)	3.69 (5.3)	1.02 (9.6)	0.65 (9.8)	1.53 (5.0)	1.21 (5.6)	0.27 (9.1)	1.56 (6.2)
Bingham Lk	12	1.23 (2.1)	0.78 (2.1)	1.10 (5.4)	3.51 (3.2)	0.91 (2.9)	0.53 (5.1)	1.47 (3.7)	1.12 (2.5)	0.25 (5.9)	1.46 (2.8)
Benson	12	1.15 (11.5)	0.75 (8.6)	1.17 (8.0)	3.62 (6.7)	0.74 (17.8)	0.53 (6.2)	1.50 (7.0)	1.17 (6.3)	0.24 (9.1)	1.55 (8.5)
Claremont	12	2.17 (4.2)	0.77 (4.3)	1.15 (6.0)	3.53 (3.1)	0.91 (10.1)	0.50 (2.5)	1.46 (2.8)	1.12 (3.4)	0.26 (5.8)	1.50 (3.7)
Luverne	12	1.25 (6.5)	0.78 (7.0)	1.07 (8.7)	3.42 (6.3)	0.94 (11.3)	0.58 (9.4)	1.42 (6.7)	1.14 (7.4)	0.25 (7.3)	1.47 (8.3)
Morris	12	1.15 (11.5)	0.73 (9.0)	1.15 (9.7)	3.47 (6.1)	0.79 (25.7)	0.49 (8.7)	1.42 (6.4)	1.12 (6.7)	0.24 (13.9)	1.49 (7.2)
Preston	11	1.18 (5.5)	0.76 (7.8)	1.05 (11.1)	3.43 (7.9)	0.85 (7.2)	0.55 (10.2)	1.43 (7.8)	1.14 (7.9)	0.24 (6.7)	1.43 (10.1)
Scotland	11	1.25 (7.8)	0.79 (7.2)	1.17 (8.2)	3.81 (7.5)	0.78 (11.2)	0.69 (6.4)	1.57 (7.3)	1.14 (6.0)	0.25 (6.9)	1.53 (7.5)
Winnebago	12	1.11 (9.9)	0.75 (7.6)	1.05 (8.3)	3.48 (5.6)	0.72 (19.7)	0.53 (3.9)	1.41 (6.7)	1.07 (6.4)	0.21 (8.4)	1.47 (7.1)
Winthrop	12	1.13 (8.7)	0.72 (8.0)	1.16 (5.6)	3.55 (3.3)	0.80 (16.4)	0.49 (5.4)	1.48 (3.2)	1.12 (3.1)	0.25 (8.9)	1.51 (6.1)
1997 to 99	118	1.20 (9.1)	0.76 (7.8)	1.12 (8.7)	3.55 (6.4)	0.85 (17.3)	0.55 (13.6)	1.47 (6.6)	1.13 (6.4)	0.25 (6.7)	1.50 (7.2)
OMP DDGS	4	0.92 (18.7)	0.61 (15.2)	1.00 (9.1)	2.97 (12.4)	0.53 (4.5)	0.50 (4.5)	1.27 (8.1)	0.98 (7.3)	0.19 (19.8)	1.39 (2.3)
Reference[b]											
NRC		1.22	0.74	1.11	2.76	0.67	0.54	1.44	1.01	0.27	1.40
HL		1.21	0.75	1.09	3.27	0.81	0.63	1.43	1.11	0.20	1.43
FRI		1.08	0.65	1.08	2.90	0.65	0.65	1.29	1.02	0.22	1.43

[a]Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.
[b]References are: NRC, 1998. (NRC), Heartland Lysine, 1998. (HL), and Feedstuffs Reference Issue, 1999. (FRI).

Table 3. Mineral composition of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older midwestern ethanol plant (OMP) and published reference values[a]

Sample origin	No. of samples	Ca (%)	P (%)	K (%)	Mg (%)	S (%)	Na (%)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)
MN-SD											
Aberdeen	12	0.03 (44.9)	0.85 (15.3)	0.84 (14.3)	0.32 (14.0)	0.33 (21.8)	0.15 (28.8)	72.1 (39.6)	21.3 (57.5)	6.0 (24.8)	175.7 (60.9)
Bingham Lk	12	0.03 (13.9)	0.94 (6.9)	0.99 (9.5)	0.34 (7.5)	0.68 (23.8)	0.16 (96.2)	56.6 (8.0)	15.5 (9.1)	5.3 (8.8)	98.1 (13.1)
Benson	12	0.08 (17.4)	0.92 (7.1)	0.99 (5.3)	0.35 (6.0)	0.40 (16.4)	0.21 (19.4)	110.0 (31.2)	15.4 (14.2)	6.3 (12.0)	118.7 (5.9)
Claremont	12	0.07 (51.2)	0.95 (4.7)	1.06 (7.1)	0.34 (4.7)	0.38 (40.8)	0.20 (55.2)	130.0 (24.0)	15.3 (11.2)	5.4 (15.2)	144.7 (12.6)
Luverne	12	0.05 (36.6)	0.91 (3.1)	0.97 (7.6)	0.37 (5.2)	0.47 (29.4)	0.20 (24.4)	96.7 (24.2)	17.4 (27.9)	6.3 (15.4)	106.9 (25.2)
Morris	12	0.13 (33.6)	0.82 (12.2)	0.94 (10.9)	0.34 (13.3)	0.74 (21.9)	0.51 (44.8)	44.7 (11.7)	16.0 (15.7)	7.6 (18.9)	156.4 (31.3)
Preston	11	0.06 (50.6)	0.99 (8.2)	1.04 (7.6)	0.36 (6.4)	0.37 (37.9)	0.20 (49.8)	312.1 (18.9)	17.8 (25.5)	5.9 (14.6)	103.2 (16.5)
Scotland	11	0.03 (21.1)	0.70 (6.4)	0.69 (10.6)	0.25 (10.7)	0.46 (6.4)	0.12 (9.4)	60.2 (7.8)	10.7 (12.9)	6.1 (14.8)	90.5 (15.4)
Winnebago	12	0.06 (15.2)	0.89 (5.5)	0.84 (4.4)	0.33 (4.3)	0.54 (14.3)	0.17 (32.8)	52.2 (6.9)	13.8 (4.4)	4.7 (10.8)	75.3 (13.9)
Winthrop	12	0.07 (15.3)	0.94 (5.6)	1.03 (5.5)	0.35 (4.7)	0.36 (9.7)	0.46 (34.4)	55.1 (10.5)	14.7 (9.9)	5.3 (19.0)	124.3 (19.1)
1997 to 99	118	0.06 (57.2)	0.89 (11.7)	0.94 (14.0)	0.33 (12.1)	0.47 (37.1)	0.24 (70.5)	97.5 (80.4)	15.8 (32.7)	5.9 (20.4)	119.8 (41.1)
OMP DDGS	4	0.44 (34.7)	0.90 (7.5)	0.99 (8.7)	0.40 (3.3)	0.51 (43.5)	0.28 (65.2)	80.2 (30.5)	49.5 (66.6)	13.5 (63.6)	219.2 (52.5)
Reference[b]											
NRC		0.22	0.83	0.90	0.20	0.32	0.27	86.0	26.0	61.0	276.0
FRI		0.38	1.02	1.08	0.38	0.32	0.86	91.0	32.0	54.0	323.0

[a]Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.
[b]References are: NRC, 1998 (NRC) and Feedstuffs Reference Issue, 1999. (FRI)

within the range of published values (0.83 to 1.02%) and similar to the phosphorus level in DDGS from the OMP (0.90%). Phosphorus is a mineral of particular interest because it is the third most expensive nutrient in the diet and has significant implications in manure management plans. Approximately 60 to 70% of the phosphorus in a corn-soybean meal diet is present as phytate-phosphorus, which is unavailable to the pig (Baker, 1991). However, the availability of phosphorus is improved in distiller's feeds due to fermentation during which a portion of the phytate-phosphorus in the corn is hydrolyzed by microbial phytase (Cromwell, 1979). This increase in phosphorus level and bioavailability in distiller's feeds, compared to corn-soybean meal diets, represents a significant cost-savings benefit to the producer.

Year-to-year differences existed for ash, DE, Mn, Zn, Cys ($P < 0.10$), Fat, TDN, ME, Met, Ile ($P < 0.05$), Ca, P, K, Mg, and Cu ($P < 0.01$). These differences in nutrient levels of MNSD DDGS were likely the result of differences in corn crop and adjustments to fermentation processes in the plants during this sampling time period.

Implications

Variability exists within and among ethanol plants and among published reference sources. Nutritionists considering using distiller's dried grains with solubles in swine diets should be aware of the variation in the nutrient content of distiller's dried grains with solubles among plants, even plants using the same fermentation and processing technology. A complete chemical analysis should be conducted a minimum of once yearly to account for differences in nutrient composition due to corn crop. When compared to common reference sources and a typical sample from the industry, distiller's dried grains with solubles produced in Minnesota and South Dakota ethanol plants are generally higher in crude fat, calculated digestible and metabolizable energy, lysine, methionine, and threonine levels. These results suggest that the distiller's dried grains from Minnesota and South Dakota ethanol plants may be better suited for use in swine diets than distiller's dried grains from other sources.

Literature Cited

Baker, D. H. 1991. Bioavailability of mineral and vitamins. In: E. R. Miller, D. E. Ullrey, and A. J. Lewis (ed.) Swine Nutrition. p 342. Butterworth-Heinemann, Stoneham, MA.

Carpenter, L. E. 1970. Nutrient composition of distillers feeds. In: Proc. Distillers Feed Res. Council, Cincinnati, OH. 25:54–61.

Cromwell, G. L. 1979. Availability of phosphorus in feedstuffs for swine. In: Proc. Distillers Feed Res. Conf., Louisville, KY. 34:40–52.

Cromwell, G. L., K. L. Herkelman, and T. S. Stahly. 1993. Physical, chemical, and nutritional characteristics of distillers dried grains with solubles for chicks and pigs. J. Anim. Sci. 71:679–686.

Cromwell, G. L., T. S. Stahly, H. J. Monegue, and J. R. Overfield. 1983. Distillers dried grains with solubles for growing-finishing swine. Kentucky Agric. Expt. Station. Progress Report 274. p 30-32. Lexington.

Feedstuffs Reference Issue. 1999. Ingredient analysis table. Miller Publishing Co., Minnetonka, MN. 71:24–31.

Heartland Lysine, Inc. 1998. Digestibility of Essential Amino Acids for Poultry and Swine. Version 3.51, Heartland Lysine, Inc., Chicago, IL.

NRC. 1998. Nutrient Requirements of Swine. 10th ed. National Academy Press, Washington, DC.

Noblet, J., and J. M. Perez. 1993. Prediction of digestibility of nutrients and energy values of pig diets from chemical analysis. J. Anim. Sci. 71:3389–3398.

Olentine, C. 1986. Ingredient profile: distillers feeds. In: Proc. Distillers Feed Conf., Cincinatti, OH. 41:13–24.

Wahlstrom, R. C., C. S. German, and G. W. Libal. 1970. Corn distillers dried grains with solubles in growing-finishing swine rations. J. Anim. Sci. 30:532–535.