# USE OF MINNESOTA-SOUTH DAKOTA REGIONAL DISTILLERS DRIED GRAINS WITH SOLUBLES IN SWINE DIETS

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## Background and Overview

The ethanol industry has experienced tremendous growth during the past decade. Ethanol production occurs as a result of fermentation of the soluble carbohydrate fraction of grain (starch). As a result, significant quantities of distillers dried grains (with or without solubles) is produced as a by-product of the ethanol industry. It is expected that the quantity of distillers dried grains with solubles will double within the next few years within the Minnesota-South Dakota region, creating an even greater supply of the by-product. In order to effectively utilize this increased supply, new markets and applications must be developed. One of the potential markets for increased use of distillers dried grains with solubles is in swine diets. However, distillers dried grains have historically had several limitations for consistent, high quantity use in swine feeds.

Since corn is the primary grain used in ethanol production, the resulting by-product has typically had the following characteristics relative to corn:

* similar, inferior amino acid profile (important for pigs and poultry)
* reduced amino acid digestibility due to heating during processing
* lower digestible and metabolizable energy due to fermentation of starch and increase in the percentage of fiber
* significantly increased phosphorus concentration and bioavailability
* increased product variability due to processing and varietal differences
* marginal cost/benefit due to incurred costs during processing and reduced nutritional value for non-ruminants

Pigs and poultry (non-ruminants) have digestive systems that are unable to utilize poor quality protein, heat damaged proteins, and significant amounts of fiber as efficiently as ruminants (cattle and sheep). Furthermore, swine and poultry feeding systems are designed to utilize dry ingredients (approximately 88 % dry matter) exclusively, whereas cattle feeding systems typically have a significant portion of the diet made up of high moisture forages. These differences in digestive system capability and feeding systems, along with marginal cost/benefit relationships in least cost diet formulations have limited the use of distillers dried grains with solubles almost exclusively to cattle feeding.

Several factors appear to offer promise for increasing the use of distillers dried grains with solubles (DDGS) in nonruminant diets. First, the construction and operation of new ethanol plants in Minnesota and South Dakota may improve nutritional value and reduce heat damage of DDGS. Secondly, increased emphasis on reducing phosphorus excretion in manure from an environmental management perspective, and the relatively high cost of providing inorganic phosphate supplements and/or phytase in swine diets, enhances of the feeding value of DDGS because of its significantly higher phosphorus concentration and bioavailability. Finally, several pork producers have observed that switching from typical corn-soy based diets to diets containing some DDGS, has changed the odor emitted from swine confinement facilities. During a time when odor control is a tremendous concern in the livestock industry, any nutritional alterations that will reduce odor while maintaining performance at the same or lower cost compared to conventional feeding programs is desperately needed.

The ultimate goal of corn growers and ethanol plants is to expand the use of DDGS in livestock feeds, particularly in feeds of non-traditional DDGS consumers (e.g. swine and poultry). To do this, pork producers and commercial feed company nutritionists must be convinced and educated that there are cost effective benefits of feeding DDGS contrary to historical experience and current knowledge. In order to effectively accomplish this goal, a series of experiments and projects were designed, and results of those at or near completion are presented in this paper.

**Development of a MN-SD Regional DDGS Nutrient Database**

***Objective:***

To utilize existing and new nutrient profile information for DDGS to determine average values within and among newer (less than five years old) ethanol plants in the Minnesota-South Dakota (MN-SD) region, and determine nutrient variability within and among plants, and also between years. These values were also to be compared to existing database values (Heartland Lysine, NRC 1998, Feedstuffs) and an industry "standard" to determine if any nutritional advantages exist in nutrient content of MN-SD DDGS compared to historical values and current product coming from other plants. This information is essential to swine nutritionists when using DDGS to precisely formulate least cost swine diets.

***Procedure:***

Ten ethanol plants participated in the study (8 – Minnesota, 2 – South Dakota) and were required to submit DDGS samples from the last day of the month, every other month, beginning January 31, 1997. Since several of the plants were not in operation right away, they began submitting samples at a later date, and as of the publication of this article, several samples remain to be submitted and/or analyzed. All samples were sent to the Swine Nutrition Laboratory, Dept. of Animal Science, Univ. of MN, St. Paul, where sub-samples were collected and sent to two commercial testing laboratories:

- Iowa Testing Laboratories, Eagle Grove, IA
  - Proximate analysis: dry matter, crude protein, crude fiber, crude fat, ash, nitrogen free extract (NFE), acid detergent fiber (ADF), and neutral detergent fiber (NDF).
  - Mineral analysis: calcium, phosphorus, potassium, magnesium, sulfur, sodium, zinc, manganese, copper, and iron.
- University of Missouri Experiment Station Chemical Lab, Columbia, MO
  - Complete amino acid profile, to include lysine, methionine, cystine, threonine, tryptophan, valine, leucine, isoleucine, phenylalanine, histidine, and arginine.

Plants were instructed to submit a sample typical of that day's production. Digestible and metabolizable energy values were calculated using the formulas:

$$DE = [(CP * 4) + (NFE * 4) + (Fat * 9)] * 4.54$$

$$ME = DE * [(0.96 – (0.2 * CP)) / 100]$$

***Results:***

Results for each plant and reference values are presented in Tables 1-3. A DDGS sample that was considered standard for the industry, coming from an older-style plant, was also analyzed and is labeled "standard." Although not presented in this paper, slight differences in nutrient level were noted between year submitted, characterizing contrasting corn crops used.

In general, variation in nutrient levels between and within plants was low (0 – 5 %), especially for dry matter, calculated DE and ME, crude protein, crude fiber, crude fat, NDF, and ADF. This indicates consistency in DDGS coming from these plants, which is logical considering that plants share information among each other and have similar operating systems. It is our belief that variation in DDGS consistency is affected by corn crop used, percent of dried solubles added back to distillers dried grains, and completeness or duration of the fermentation process which affects the degree of starch removal.

Crude fat and calculated DE and ME values for MN-SD DDGS are significantly higher than published book values. Also, ADF is slightly less and NDF slightly more than NRC (1998) levels. Since the difference between NDF and ADF is the amount of hemicellulose in the feed, the amount of hemicellulose in MN-SD DDGS is higher than normally found, and since hemicellulose is slightly more digestible than the ADF fraction, may provide a slight advantage for MN-SD DDGS compared to book values.

Average lysine and threonine values for MN-SD DDGS are higher than those published in NRC (1998) and 1998 Feedstuffs Reference Issue (FRI), but similar to Heartland Lysine (HL) values. Average methionine level is identical to NRC but lower than published in HL and FRI. Average tryptophan level is within range of published book values. Since lysine is the first limiting amino acid in corn-soybean meal swine diets, MN-SD DDGS would be a more valuable source than other DDGS sources because less soybean meal would be needed to meet the desired lysine level in the diet. However, level of lysine level variability within some plants is of concern because increased variability means reduced predictability of lysine levels for precise diet formulation. Variability within plant for methionine, threonine, and tryptophan is generally acceptable. It is quite possible that most of the variability in lysine level is due to variability in lysine of the original corn used. This stresses the importance of understanding nutrient specifications of the corn being used in each plant.

Average crude protein level of MN-SD DDGS is somewhat higher than published book values, indicating that more complete starch removal may be occurring due to use of newer fermentation technology. From a nutritional perspective, the higher crude protein level may result in increased nitrogen excretion and ammonia levels when DDGS is added to swine diets. Increased energy is also required by the animal to excrete the excess nitrogen, leaving less energy available to the animal for production.

Levels of Ca, K, Mg, S, Na, Zn, Mn, Cu, and Fe are of minor interest due to their low cost, and relatively low concentrations. Phosphorus is the third most expensive nutrient (behind energy and amino acids) in swine diets, and averaged within the range of published book values. Ash values were lower for MN-SD DDGS compared to the sample taken from an older plant. High levels of ash can dilute other nutrients in the feedstuff, so having a lower ash content can be an advantage.

## Determine Energy, Nitrogen, and Phosphorus Digestibility of DDGS in the Growing and Finishing Pig

### *Objective:*

To determine DE, ME and available phosphorus values, which cannot be determined by chemical analysis, for MNSD Region DDGS sources to add to the nutrient database. Nitrogen digestibility determinations will be used to calculate digestible crude protein and provide some initial evidence of what we might expect when determining ileal amino acid digestibility.

### *Procedure:*

A total of 16 crossbred growing pigs (initial weight 63 lbs) (8 pigs/group, 2 replications/group, 2 separate groups) and 16 crossbred finishing pigs (initial weight 185 lbs) were used to evaluate DDGS energy, nitrogen, and phosphorus digestibility at two different phases of growth to determine if DDGS is well utilized in the grower and finisher phases or if it is better utilized in only the finisher phase. Pigs were randomly allotted by weight and ancestry to one of four dietary treatments. Pigs were placed in individual stainless steel collection cages at the St. Paul Swine Research unit, and fed either a control diet (100% corn-soybean basal diet), a 10% DDGS diet (with 90% basal diet), a 20% DDGS diet (with 80% basal diet), or a 30% DDGS diet (with 70% basal diet) (Tables 4 and 5). Total lysine and phosphorus were held constant across all diets.

Pigs were allowed a seven day acclimation period to ensure all pigs were eating well and were adjusted to the individual crates. A three-day collection period immediately followed the acclimation period. Pigs were fed as close as possible to ad libitum while minimizing feed wastage during the entire 10-day study. Feces and urine were collected during the 3-day collection period to determine energy and nitrogen digestibility. Temperature was maintained at approximately 72°F throughout the experiment, and all animals will be allowed ad libitum access to water.

All feces generated from each individual pig over the collection period was collected daily in labeled plastic bags and frozen for later subsequent analysis. Samples were pooled for each pig. Every attempt was made to separate waste feed from feces when collecting each sample. Waste feed was collected, weighed, recorded and discarded.

**Table 4. Early grower experimental diets, DDGS nutrient balance study.**

| Ingredient,% | Control | 10% DDGS | 20% DDGS | 30% DDGS |
|---|---|---|---|---|
| Corn | 68.12 | 61.31 | 54.50 | 47.68 |
| Soybean Meal, 44% | 29.30 | 26.37 | 23.44 | 20.51 |
| MNSD DDGS | 0.00 | 10.00 | 20.00 | 30.00 |
| Limestone | 0.93 | 1.01 | 1.09 | 1.18 |
| Dicalcium Phosphate | 0.75 | 0.50 | 0.25 | 0.00 |
| Salt, NaCl | 0.50 | 0.45 | 0.40 | 0.35 |
| Vitamin Premix | 0.30 | 0.27 | 0.24 | 0.21 |
| Trace Mineral Premix | 0.10 | 0.09 | 0.08 | 0.07 |

**Table 5. Late finisher experimental diets, DDGS nutrient balance study.**

| Ingredient,% | Control | 10% DDGS | 20% DDGS | 30% DDGS |
|---|---|---|---|---|
| Corn | 82.11 | 73.90 | 65.69 | 57.48 |
| Soybean Meal, 44% | 15.34 | 13.80 | 12.27 | 10.74 |
| MNSD DDGS | 0.00 | 10.00 | 20.00 | 30.00 |
| Limestone | 0.81 | 0.92 | 1.04 | 1.15 |
| Dicalcium Phosphate | 0.85 | 0.57 | 0.28 | 0.00 |
| Salt, NaCl | 0.50 | 0.45 | 0.40 | 0.35 |
| Vitamin Premix | 0.30 | 0.27 | 0.24 | 0.21 |
| Trace Mineral Premix | 0.10 | 0.09 | 0.08 | 0.07 |

Total urinary output was collected from each pig daily in plastic containers located under funnels of the metabolism cages. One hundred milliliters of 6N hydrochloric acid (HCl) was added to urine collection containers daily to limit microbial growth and reduce loss of ammonia. Total urine volume was measured daily, and a 200-ml subsample was placed in labeled, capped, plastic bottles and frozen. At the end of the collection period, all subsamples were thawed, combined in proportion to daily volume for each pig and frozen until subsequent laboratory analysis can be conducted.

The DDGS used in this study was analyzed for dry matter, crude protein, mineral content, amino acid profile, and energy. Gross energy of feed, feces, and urine samples was determined by bomb calorimetry and subsequent digestible and metabolizable energy values were calculated similar to the DDGS database study. Analysis of fecal and feed dry matter will also be conducted in the Swine Nutrition Lab. Least squares means analysis using GLM procedure of SAS was conducted, with the model including the effects of treatment and group.

*Results:*

Results are presented in Figures 1,2, and 3 . During the grower experiment, GE and nitrogen intake tended to increase with increasing DDGS level in the diet. Digestible and metabolizable energy were lower for the control diet compared to the 10, 20, and 30% DDGS ($P < 0.01$). When compared to published values, MN-SD DDGS had consistently higher DE and ME values. Nitrogen retention (%) did not differ between treatments ($P > 0.10$), but adding 30% DDGS did increase ($P < .10$) nitrogen excretion compared to the control. Feeding 20% DDGS increased phosphorus retention compared to the control and 30% DDGS diets. ($P < .10$)

During the late finisher experiment, nitrogen intake was lower in the control diet than the 10, 20, and 30% DDGS diets ($P < 0.01$). DE and ME were greater in the 10% DDGS diet as compared to the 30% DDGS ($P < 0.10$). Nitrogen retention (%) did not differ between treatments ($P > 0.10$). Again, adding 30% DDGS increased ($P < .10$) nitrogen excretion compared to the control. Feeding 10% DDGS increased phosphorus retention (%) compared to the control ($P < 0.10$).

These results suggest that digestibility of phosphorus in MN-SD DDGS is better than that for corn or soybean meal. Adding up to 20% DDGS in grower diets and up to 10% DDGS in finisher diets maximizes phosphorus retention and minimizes phosphorus excretion. Adding 10-20% DDGS in grower diets and 10% DDGS in finisher diets is comparable to the control diet and should minimize nitrogen excretion and support pig growth

MN-SD DDGS appears to have a higher feeding value than DDGS from other sources. Energy (DE and ME) values are higher for early grower pigs than for later finisher pigs. Adding 10-20% DDGS will increase DE and ME intake and improve phosphorus utilization without limiting performance but may increase nitrogen excretion.

**Figure 1. Comparison of ME values for MN-SD DDGS to published values.**

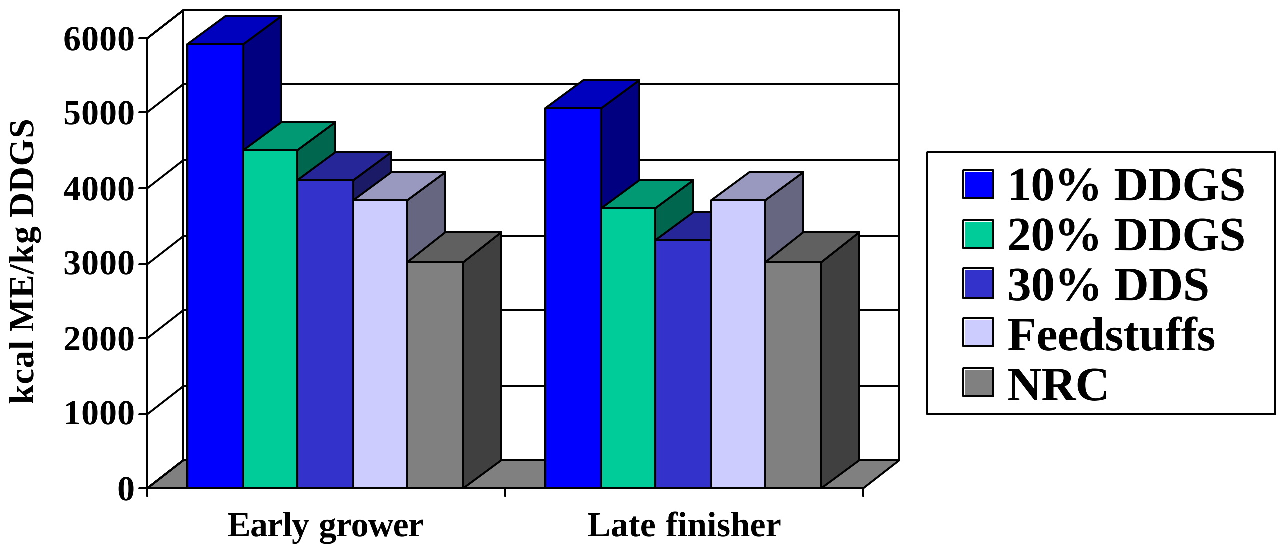


**Figure 2. Effect of 10, 20, and 30% MN-SD DDGS on % nitrogen retained.**

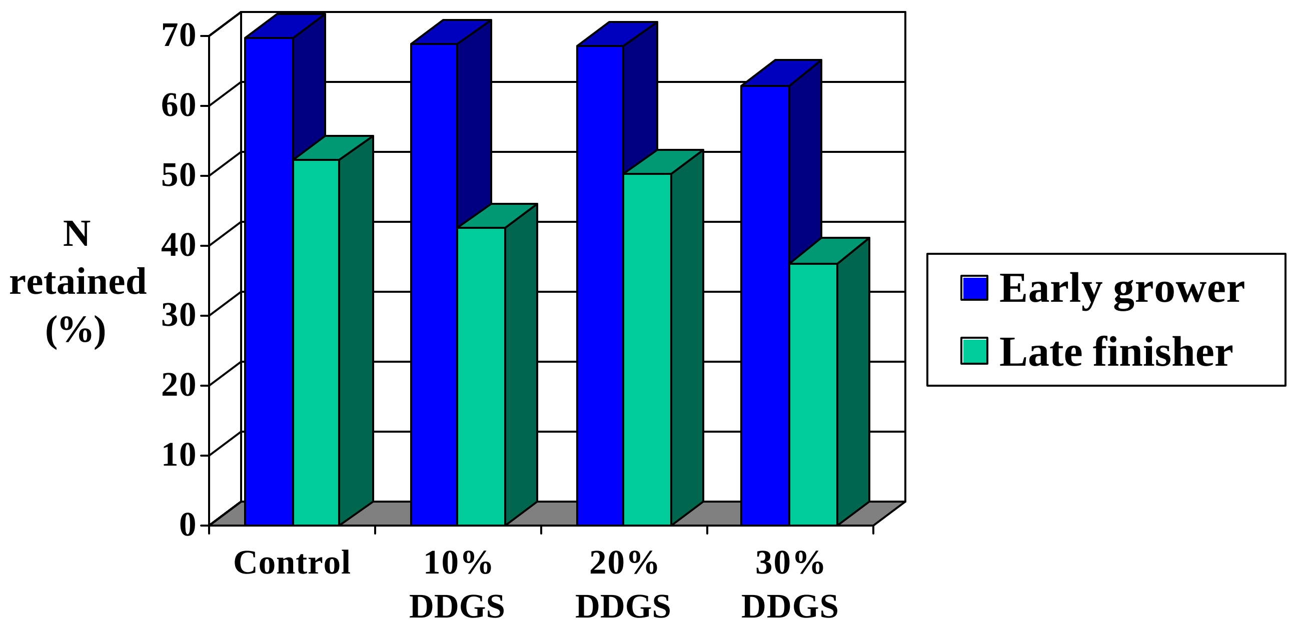
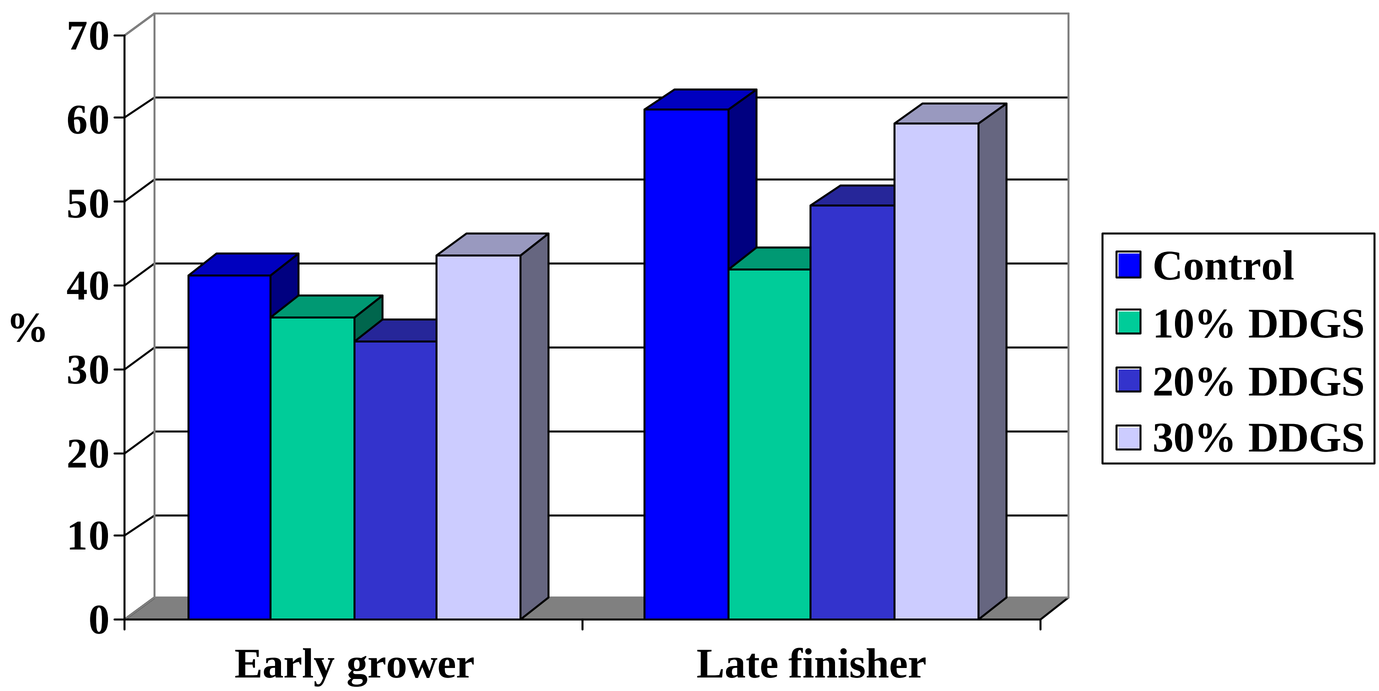


**Figure 3. Effect of 10, 20, and 30% MN-SD DDGS on % phosphorus excreted.**



**Comparison of Odor Characteristics of Swine Manure with and without DDGS**

***Objective:***

To determine if the use of 20% DDGS in swine diets will reduce odor, ammonia, and/or hydrogen sulfide levels emitted from a simulated deep pit manure storage system. Energy, nitrogen, and phosphorus excretion of experimental diets are also determined to augment the previous nutrient balance study.

*Procedure:*

A typical three-phase corn-soybean meal based grow-finish diet sequence was compared to a three-phase corn-soybean meal- 20% DDGS diet sequence. Twenty PIC barrows were brought from the West Central Experiment Station in Morris, Minnesota to the St. Paul Swine Research unit. The pigs were weighed and randomly assigned to one of two dietary treatments (8 pigs/dietary treatment). Eight pigs (4 pigs/dietary treatment) were immediately placed in metabolism crates. While in the metabolism crates, the pigs were fed 3 times daily as close to ad libitum as possible without allowing pigs to waste feed. The remaining 8 pigs were housed in pens in the Grow-Finish room and were allowed ad libitum access to their respective diets. All pigs had ad libitum access to water while in the metabolism crates and in the Grow-Finish pens. Pigs remained in the metabolism crates for two weeks. After two weeks, they were weighed and allowed to return to the pen of their respective treatment group in the Grow-Finish room. The 8 experimental pigs (4 pigs/dietary treatment) that were previously in the Grow-Finish room were weighed and placed in the metabolism crates. This rotation continued for the 10-week duration of the trial.

Manure (urine and feces mixture) from each of the 8 pigs in the metabolism crates was collected once daily except on the last three days of weeks 2, 6, and 10, when collection was conducted for the digestibility/excretion study. Manure volume was recorded and individual manure samples (total=8) were mixed thoroughly to ensure uniform consistency of each sample. Each sample was then divided equally into two separate containers to get a total of 16 manure containers (2 container/pigs). The contents of each container was then emptied into the corresponding Deep Pit Simulator Model (total=16).

The Deep Pit Simulator Models (DPSM) are constructed of 5 feet of PVC pipe and are 16 inches in diameter. The pipe has been set upright in a plastic tub and the bottom of the PVC pipe was filled with concrete. DPSM were stored in two nutrient balance rooms of the swine barn. Each room housed 8 DPSM (4 / dietary treatment). The temperature of the DPSM rooms was recorded daily.

During the last three days of weeks 2, 6, and 10, samples were collected to measure the digestibility of the two treatment diets. The crates were thoroughly cleaned and screens were placed under each crate to allow for separate collection of urine and fecal samples. Urine volume was measured and recorded twice daily and a sub-sample of the urine was placed in labeled, capped, plastic bottles and refrigerated until subsequent laboratory analysis could be conducted. Fecal samples were collected on the screen under the metabolism crates. The feces generated over the three-day period was collected daily, pooled, and placed in a labeled plastic bag and frozen for later subsequent analysis. Bomb calorimetery was used to determine the gross energy of the fecal, urine, and feed samples. Kjeldahl analysis was used to determine the nitrogen level of the fecal, urine, and feed samples.

Air samples were collected on the Tuesday of each week. Samples were collected approximately 10 inches above the surface of the manure in collection bags using a vacuum box at a flow rate of 40 L/min. Air samples were analyzed for hydrogen sulfide concentration using the Jerome ™ meter and ammonia concentration was measured using Sensidyne™ tubes. In addition, the 16 air samples collected during weeks 1, 3, 6, and 9 were evaluated for odor utilizing an odor panel and olfactometer.

**Preliminary Results:**

Statistical analysis for the data set was determined by using the SAS and Macanova programs. The preliminary results indicate that there was not a significant effect of dietary treatment on hydrogen sulfide (P=0.3884), ammonia (P=0.1736), or odor levels (P=0.9960) during the 10-week trial. This indicates that adding DDGS to the grow-finish diet did not significantly alter the hydrogen sulfide, ammonia, or odor levels in the manure. This was due, in part, to the large variation in the data collected as can be seen in Figures 4, 5, and 6.

The results did indicate a significant difference in odor between rooms (P=0.0006). We were unable to control the temperature in the rooms, which resulted in a 6.4° F difference between the two rooms. Room 1 was the warmer of two rooms, averaging 70.3° F for the 10-week period and had higher odor levels than room 2. No differences were noted between dietary treatment, although this may be due to the method used (Figure 4). It is likely that more fermentation occurred in room 1 due to the higher temperature, resulting in increased odor, regardless of dietary treatment, compared to room 2.

Hydrogen sulfide (P=0.0001) and ammonia (P=0.001) levels increased significantly during the trial. Figures 5 and 6 show the increase of these two gases during the 10-week period. This can be explained by the increased production of the gases due to increased fermentation as the bacteria population grew over time. Odor appeared to follow the same trend, although the change in odor units with time was not statistically significant (P=0.0636).

The lab work is not yet complete for the nutrient digestibility/excretion portion of this experiment.

**Figure 4. Odor detection threshold, deep pit simulators, MN-SD DDGS odor study.**

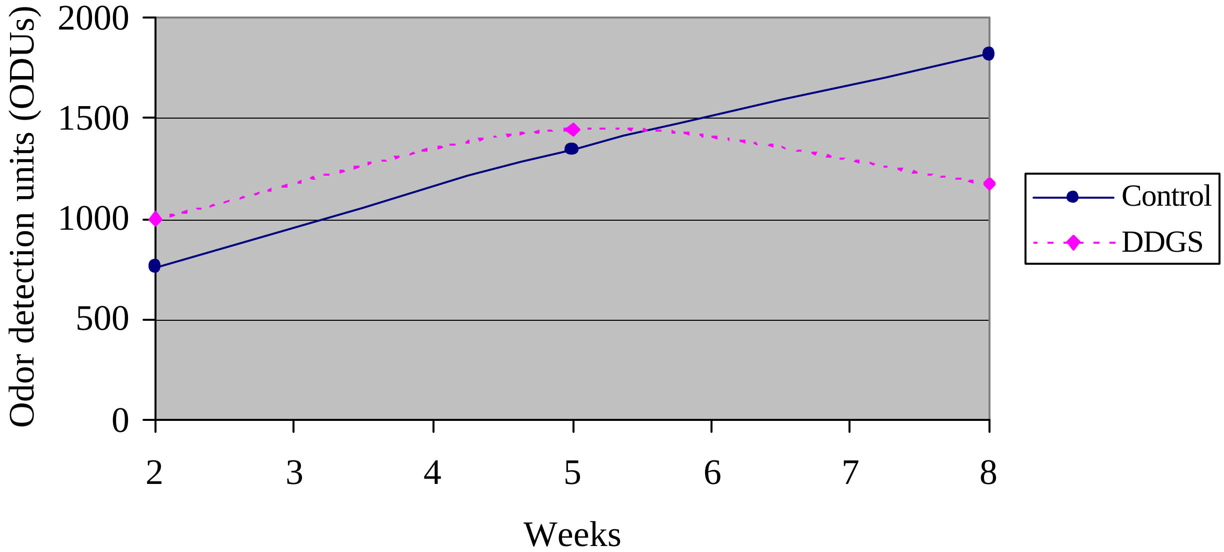



**Figure 5. Hydrogen sulfide levels of deep pit simulators, MN-SD DDGS odor study.**

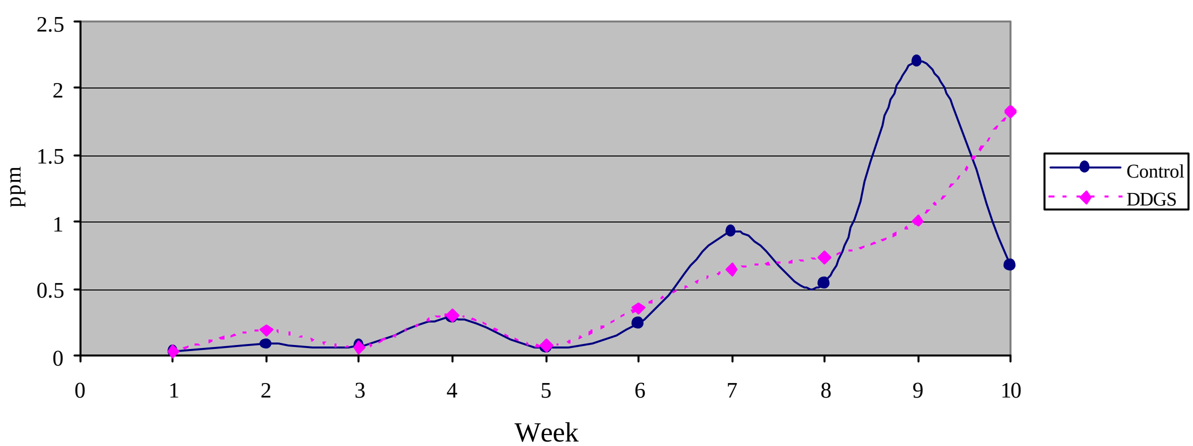
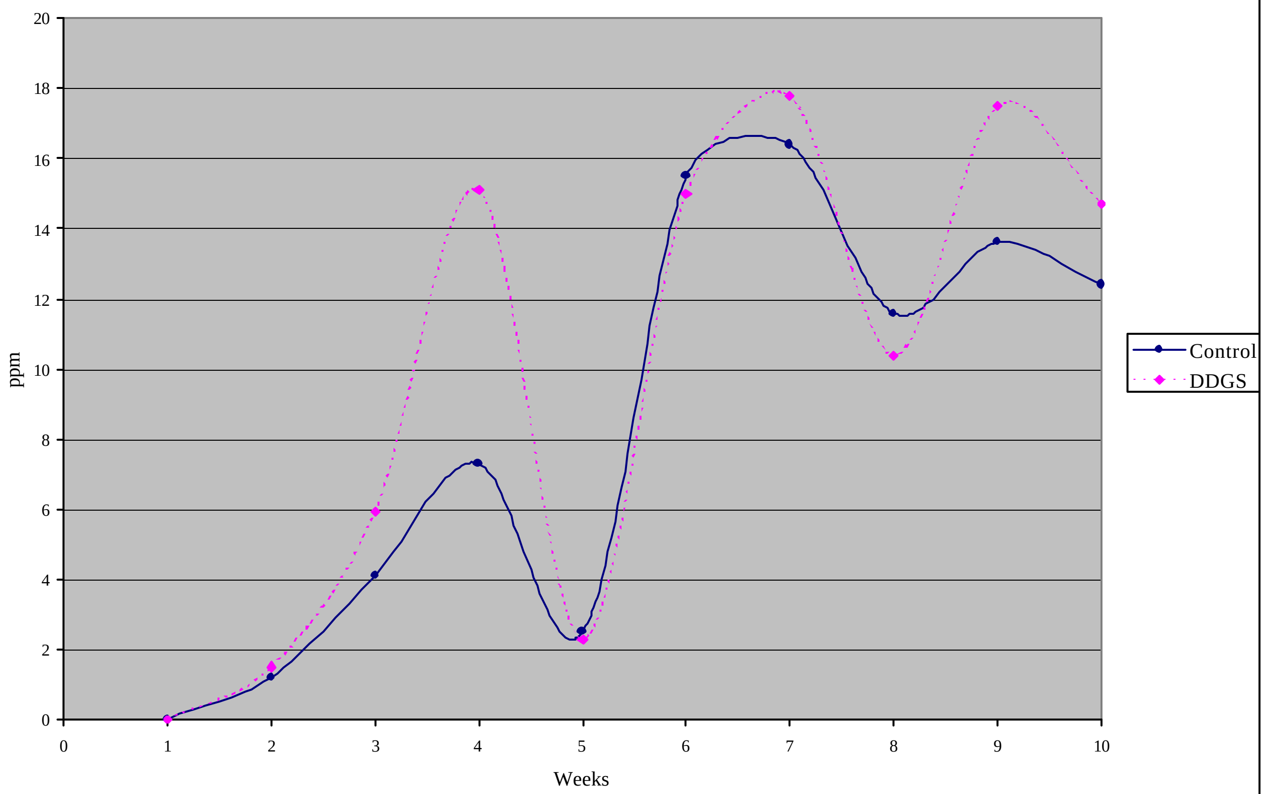


**Figure 6. Ammonia concentration, deep pit simulators, MN-SD DDGS odor study.**



## On-going Research

### ***Determine ileal amino acid digestibility values for MNSD DDGS and various drying conditions, colors, plants, and DDGS fractions.***

There is wide variation in the amino acid digestibility of various byproducts fed to pigs, and DDGS is no exception. There is also considerable variation in the color of DDGS among and within plants. Reasons for this wide variation involves the extent of fermentation, the amount of solubles added back to the distiller's grains, as well as the amount and duration of heat applied during drying of DDGS. The Maillard reaction is a well established phenomenon in which amino acids are chemically bound to carbohydrate during heating, and rendering them less digestible. Feed manufacturers routinely visually inspect heat processed feed ingredients for darkness of color and associate darker colored heat processed ingredients with lower amino acid digestibility. Thus, it needs to be established if color (and dryer temperature/duration) of DDGS affects energy and nitrogen digestibility. An ileal cannulation experiment to determine the apparent and true digestible amino acid levels of several sources of DDGS is currently underway.

### Determine Least Cost Formulas, Economic Competitiveness, and Maximum Inclusion Rates of MN DDGS Sources

*Objective:*

To use nutritional values and information obtained in previous experiments to determine example diet formulations and maximum inclusion rates, and DDGS cost relationships with corn, soybean meal and other competing dietary ingredients.

**Table 1.** **Proximate analysis of Distiller's Dried Grains with Solubles (DDGS) originating from newer (< 5 years old) ethanol plants in Minnesota and South Dakota compared to a standard sample and referenced values.[1]**

| Sample origin | # of samples | DM (%) | CP (%) | Fat (%) | Fiber (%) | Ash (%) | NFE (%) | ADF (%) | NDF (%) | DE[2] (kcal/lb) | ME[2] (kcal/lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MN-SD | | | | | | | | | | | |
| Plant 1 | 12 | 90.2 (1.0) | 30.9 (7.7) | 9.9 (26.9) | 9.1 (6.8) | 6.4 (15.4) | 43.8 (8.6) | 18.1 (7.7) | 44.5 (5.1) | 1761 (4.0) | 1592 (4.1) |
| Plant 2 | 12 | 89.1 (1.3) | 31.4 (2.1) | 11.4 (5.6) | 9.2 (6.0) | 5.6 (9.0) | 42.4 (3.3) | 13.8 (—) | 40.6 (—) | 1806 (0.9) | 1632 (0.9) |
| Plant 3 | 12 | 90.0 (2.1) | 30.7 (7.0) | 10.2 (9.3) | 8.8 (9.5) | 5.5 (17.1) | 44.8 (7.3) | 15.8 (8.6) | 44.5 (4.4) | 1789 (1.5) | 1618 (1.6) |
| Plant 4 | 12 | 90.0 (0.6) | 28.7 (4.2) | 10.7 (6.0) | 8.3 (5.9) | 5.4 (12.8) | 46.9 (2.9) | 15.4 (11.4) | 42.8 (3.8) | 1812 (1.3) | 1646 (1.3) |
| Plant 5 | 12 | 88.7 (0.8) | 29.5 (3.4) | 10.8 (5.6) | 8.7 (4.4) | 5.2 (7.8) | 45.8 (3.9) | 17.1 (6.8) | 41.9 (2.5) | 1809 (0.7) | 1642 (0.7) |
| Plant 6 | 11 | 89.8 (1.4) | 31.6 (5.0) | 10.8 (4.4) | 9.7 (5.3) | 5.7 (16.6) | 42.2 (5.4) | 18.5 (10.3) | 49.1 (3.2) | 1782 (1.5) | 1610 (1.8) |
| Plant 7 | 11 | 88.4 (1.1) | 30.3 (2.5) | 11.3 (5.1) | 8.2 (5.8) | 5.4 (12.3) | 44.9 (2.8) | 12.6 (10.2) | 39.0 (5.6) | 1824 (1.3) | 1654 (1.2) |
| Plant 8 | 8 | 87.9 (1.3) | 31.7 (2.8) | 9.9 (11.0) | 9.2 (11.2) | 6.7 (9.6) | 42.5 (3.2) | 14.4 (8.3) | 47.9 (7.9) | 1752 (2.6) | 1584 (2.7) |
| Plant 9 | 5 | 86.4 (1.0) | 29.8 (3.0) | 11.2 (8.8) | 8.8 (7.6) | 6.1 (10.4) | 44.0 (2.8) | 12.7 (10.6) | 41.2 (5.5) | 1799 (2.3) | 1634 (2.3) |
| Plant 10 | 5 | 88.0 (1.1) | 30.1 (4.0) | 10.9 (5.4) | 9.0 (5.1) | 6.8 (8.7) | 43.3 (3.5) | 13.0 (7.4) | 41.7 (6.0) | 1777 (0.7) | 1612 (0.7) |
| 1997 - 99 | 100 | 89.1 (1.2) | 30.5 (1.4) | 10.7 (1.0) | 8.9 (0.6) | 5.8 (0.7) | 44.2 (2.2) | 15.7 (2.1) | 43.5 (3.0) | 1793 (33.7) | 1624 (32.0) |
| Standard | 1 | 89.5 | 29.0 | 9.7 | 7.4 | 8.0 | 45.9 | 16.7 | 38.0 | 1756 | 1596 |
| Reference[3] | | | | | | | | | | | |
| NRC | | 93.0 | 29.8 | 9.0 | 4.8 | | | 17.5 | 37.2 | 1564 | 1378 |
| HL | | 90.8 | 28.5 | | | | | | | | |
| FRI | | 93.0 | 29.0 | 8.6 | 9.1 | | | | | | 1747 |

[1] Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

[2] DE = [(CP * 4) + (NFE * 4) + (Fat * 9)] * 4.54, ME = DE * [(0.96 - (0.2 * CP))/100].

[3] References are: Nutrient Requirements of Swine, 10th ed., 1998.
Heartland Lysine, Inc. Amino Acid Digestibility Tables, 1998.
Feedstuffs Reference Issue, Vol. 69 Num. 10, July 24, 1997.

**Table 2. Mineral Composition of Distiller's Dried Grains with Solubles (DDGS) originating from newer (< 5 years old) ethanol plants in Minnesota and South Dakota compared to a standard sample and referenced values.[1]**

| Sample origin | # of samples | Ca (%) | P (%) | K (%) | Mg (%) | S (%) | Na (%) | Zn (ppm) | Mn (ppm) | Cu (ppm) | Fe (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MN-SD | | | | | | | | | | | |
| Plant 1 | 12 | 0.04 (14.4) | 0.94 (7.0) | 0.99 (9.8) | 0.34 (7.7) | 0.68 (24.2) | 0.16 (97.7) | 56.6 (8.2) | 15.5 (9.3) | 5.3 (9.4) | 98.1 (13.4) |
| Plant 2 | 12 | 0.07 (53.6) | 0.94 (4.5) | 1.06 (7.4) | 0.34 (4.7) | 0.38 (41.7) | 0.20 (55.7) | 130.1 (24.5) | 15.3 (11.3) | 5.4 (15.7) | 144.7 (12.8) |
| Plant 3 | 12 | 0.13 (33.7) | 0.82 (12.6) | 0.94 (11.1) | 0.34 (13.5) | 0.75 (22.4) | 0.51 (45.8) | 44.6 (12.0) | 16.0 (16.1) | 7.6 (19.2) | 156.3 (32.0) |
| Plant 4 | 12 | 0.06 (14.7) | 0.90 (5.5) | 0.84 (4.4) | 0.33 (4.0) | 0.54 (14.7) | 0.17 (33.2) | 52.2 (7.0) | 13.8 (4.5) | 4.7 (10.9) | 75.3 (14.2) |
| Plant 5 | 12 | 0.07 (18.4) | 0.94 (5.7) | 1.03 (5.5) | 0.34 (4.9) | 0.36 (10.1) | 0.46 (34.9) | 55.1 (10.7) | 14.7(10.2) | 5.3 (19.5) | 124.3 (19.5) |
| Plant 6 | 11 | 0.03 (20.5) | 0.70 (6.6) | 0.69 (10.8) | 0.25 (10.1) | 0.46 (6.5) | 0.12 (9.9) | 60.2 (7.9) | 10.7 (13.3) | 6.1 (15.1) | 90.5 (15.8) |
| Plant 7 | 11 | 0.08 (21.1) | 0.93 (7.2) | 0.99 (5.7) | 0.35 (6.6) | 0.51 (13.1) | 0.21 (18.7) | 110.5 (33.3) | 15.7 (13.2) | 6.4 (12.7) | 119.0 (6.3) |
| Plant 8 | 8 | 0.03 (32.9) | 0.86 (19.1) | ------- | 0.32 (16.5) | 0.36 (5.6) | 0.13 (27.0) | 58.4 (31.8) | 22.1 (71.2) | 5.3 (19.7) | 187.0 (72.8) |
| Plant 9 | 5 | 0.04 (22.9) | 0.94 (2.4) | 1.02 (5.0) | 0.37 (1.2) | 0.44 (14.4) | 0.19 (30.0) | 87.1 (29.0) | 15.3 (17.6) | 6.0 (8.7) | 107.1 (13.9) |
| Plant 10 | 5 | 0.06 (58.7) | 1.01 (11.1) | 1.09 (4.0) | 0.36 (5.9) | 0.40 (18.7) | 0.20 (33.2) | 309.3 (6.6) | 15.9 (15.0) | 5.9 (9.4) | 110.6 (20.3) |
| 1997 - 99 | 100 | 0.06 (0.03) | 0.89 (0.09) | 0.94 (0.11) | 0.33 (0.03) | 0.49(0.15) | 0.25 (0.15) | 83.9(53.0) | 15.3 (4.3) | 5.8 (1.0) | 120.7 (44.4) |
| Standard | 1 | 0.67 | 0.98 | 1.12 | 0.38 | 0.84 | 0.55 | 84.9 | 45.8 | 7.8 | 262.6 |
| Reference[2] | | | | | | | | | | | |
| NRC | | 0.22 | 0.83 | 0.90 | 0.20 | 0.32 | 0.27 | 86 | 26 | 61 | 276 |
| HL | | | | | | | | | | | |
| FRI | | 0.38 | 1.02 | 1.08 | 0.38 | 0.32 | 0.86 | 91 | 32 | 54 | 323 |

[1] Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

[2] References are: Nutrient Requirements of Swine, 10th ed., 1998.
Heartland Lysine, Inc. Amino Acid Digestibility Tables, 1998.
Feedstuffs Reference Issue, Vol. 69 Num. 10, July 24, 1997.

**Table 3.** **Essential amino acid level of Distiller's Dried Grains with Solubles (DDGS) originating from newer (< 5 years old) ethanol plants in Minnesota and South Dakota compared to a standard sample and referenced values.[1]**

| Sample origin | # of samples | Lys (%) | Met (%) | Thr (%) | Trp (%) | Val (%) | Ile (%) | Leu (%) | His (%) | Phe (%) | Arg (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MN-SD | | | | | | | | | | | |
| Plant 1 | 12 | 0.74 (18.0) | 0.53 (6.4) | 1.17 (6.4) | 0.27 (8.3) | 1.55 (8.6) | 1.17 (8.2) | 3.62 (6.8) | 0.75 (8.7) | 1.50 (7.1) | 1.15 (11.7) |
| Plant 2 | 12 | 0.91 (10.3) | 0.50 (2.5) | 1.12 (3.4) | 0.26 (5.5) | 1.50 (3.8) | 1.15 (6.1) | 3.53 (3.2) | 0.77 (4.3) | 1.45 (2.9) | 1.22 (4.2) |
| Plant 3 | 12 | 0.79 (26.2) | 0.49 (8.6) | 1.12 (7.0) | 0.24 (13.9) | 1.49 (7.4) | 1.15 (10.0) | 3.47 (6.2) | 0.73 (9.3) | 1.42 (6.6) | 1.15 (11.7) |
| Plant 4 | 12 | 0.72 (20.1) | 0.53 (4.0) | 1.07 (6.5) | 0.21 (8.7) | 1.47 (7.3) | 1.05 (8.5) | 3.48 (5.7) | 0.72 (7.6) | 1.41 (6.8) | 1.11 (10.0) |
| Plant 5 | 12 | 0.81 (16.5) | 0.50 (5.7) | 1.12 (3.2) | 0.24 (8.8) | 1.51 (6.2) | 1.16 (5.6) | 3.55 (3.4) | 0.72 (8.2) | 1.48 (3.3) | 1.13 (8.9) |
| Plant 6 | 11 | 0.78 (11.4) | 0.69 (6.5) | 1.14 (6.2) | 0.25 (7.1) | 1.53 (7.9) | 1.17 (8.5) | 3.81 (7.7) | 0.79 (7.3) | 1.57 (7.6) | 1.25 (11.4) |
| Plant 7 | 11 | 0.90 (2.6) | 0.54 (5.6) | 1.12 (2.5) | 0.2 (5.3) | 1.47 (3.0) | 1.11 (5.4) | 3.53 (2.9) | 0.79 (2.3) | 1.48 (3.5) | 1.23 (2.2) |
| Plant 8 | 8 | 1.02 (7.0) | 0.63 (9.5) | 1.18 (5.4) | 0.27 (8.3) | 1.58 (4.6) | 1.17 (6.9) | 3.67 (4.8) | 0.82 (5.4) | 1.52 (4.5) | 1.29 (4.8) |
| Plant 9 | 5 | 0.91 (16.0) | 0.59 (12.1) | 1.13 (8.5) | 0.25 (8.5) | 1.49 (10.7) | 1.10 (10.1) | 3.44 (7.5) | 0.79 (7.9) | 1.42 (8.1) | 1.22 (7.9) |
| Plant 10 | 5 | 0.84 (9.5) | 0.56 (12.5) | 1.14 (6.9) | 0.25 (6.3) | 1.54 (7.9) | 1.14 (8.7) | 3.61 (8.2) | 0.79 (7.8) | 1.49 (8.0) | 1.21 (5.9) |
| 1997 - 99 | 100 | 0.83 (17.7) | 0.55 (13.5) | 1.13 (5.9) | 0.24 (10.3) | 1.51 (6.8) | 1.14 (8.0) | 3.57 (6.1) | 0.76 (7.9) | 1.48 (6.4) | 1.19 (9.1) |
| Standard | 1 | 0.68 | 0.49 | 0.99 | 0.22 | 1.31 | 1.04 | 3.22 | 0.68 | 1.30 | 1.07 |
| Reference[2] | | | | | | | | | | | |
| NRC | | 0.67 | 0.54 | 1.01 | 0.27 | 1.40 | 1.11 | 2.76 | 0.74 | 1.44 | 1.22 |
| HL | | 0.81 | 0.63 | 1.11 | 0.20 | 1.43 | 1.09 | 3.27 | 0.75 | 1.43 | 1.21 |
| FRI | | 0.65 | 0.65 | 1.02 | 0.22 | 1.43 | 1.08 | 2.90 | 0.65 | 1.29 | 1.08 |

[1] Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

[2] References are: Nutrient Requirements of Swine, 10th ed., 1998.
Heartland Lysine, Inc. Amino Acid Digestibility Tables, 1998.
Feedstuffs Reference Issue, Vol. 69 Num. 10, July 24, 1997.