Chapter 28

Impact of Diet Formulation Methods and Tools on Assessing Value of DDGS

Introduction

Nutrient variability

One of the challenges of obtaining the best economic and nutritional value from U.S. DDGS is to know actual nutrient content and digestibility of the DDGS source being used. **Table 1** shows an example summary of averages and ranges in nutrient content and digestibility for swine among DDGS sources. Refer to **Chapter 4 "Nutrient Composition and Digestibility of DDGS: Variability and *In Vitro* Measurement"** section of this handbook for specific recommendations on nutrient content and digestibility for various animal species.

Table 1. Nutrient composition and digestibility of DDGS samples from various ethanol plants in the Midwest U.S.[1]

Nutrient	Average	Minimum	Maximum
Dry matter, %	89.22	86.22	92.4
Crude protein, %	30.8	27.3	33.9
Crude fat, %	11.2	3.5	13.5
Crude fiber, %	7.41	5.37	10.58
ME, kcal/kg	3,855	3,504	4,087
Calcium, %	0.05	0.02	0.51
Phosphorus, %	0.61	0.51	0.74
Digestible P, %	0.36	0.28	0.47
Lysine, %	0.97	0.61	1.19
SID lysine, %	0.65	0.33	0.77
Methionine, %	0.63	0.54	0.76
SID methionine, %	0.47	0.40	0.66
Threonine, %	1.15	1.01	1.32
SID threonine, %	0.87	0.68	0.96
Tryptophan %	0.24	0.18	0.34
SID tryptophan, %	0.17	0.10	0.21

[1]Adapted from www.ddgs.umn.edu, Urriola (2005), and Stein and Shurson (2009).

Knowing the nutrient content and digestibility of the specific source of DDGS being fed is the single most important factor for assessing economic value and obtaining optimal animal performance. Overestimating nutrient content of DDGS, or any other feed ingredient, can result in reduced growth performance when added to complete feeds and fed to animals. This is more likely to occur when DDGS is used at high dietary inclusion rates compared to low inclusion rates. In contrast, underestimating nutrient content of DDGS can result in feeding excessive nutrients above the animal's requirement, underestimating economic value, and increasing nutrient excretion in manure.

Decision tools to evaluate the economic value for use of DDGS in livestock and poultry diets

Several DDGS value calculator tools have been developed to determine DDGS feeding value for livestock and poultry. These tools are extremely useful for determining the actual economic value of DDGS in specific livestock and poultry diets and should be used when evaluating whether the current price for DDGS is economical relative to its nutrient contributions and price relative to other competing ingredients. The most recent and comprehensive DDGS evaluation tool was developed by researchers at Iowa State University (Dahlke and Lawrence, 2008) and is useful for a wide variety of diets and food animal species: http://www.matric.iastate.edu/DGCalculator *SESAME,* www.sesamesoft.com developed by researchers at Ohio State (Drs. Normand St-Pierre, Branislav Cobanov and Dragan Glamocic, 2007), is a comprehensive tool to help livestock and poultry producers make better feed-purchasing choices. Researchers at the University of Nebraska (C. Buckner, G. Erickson, T. Klopfenstein, D. Mark, and V. Bremer, 2006) developed a corn co-product cost calculator for beef cattle Cattle Coproduct Optimizer Decision Evaluator, and 3 DDGS evaluation tools have been developed specifically for swine:

University of Illinois DDGS Calculator developed by Drs. Beob G. Kim and Hans H. Stein (Dec. 2007).

DDGS Cost Calculator for Swine - developed by Dr. Bob Thaler, South Dakota State University Extension Swine Specialist (Sep. 2002).

DDGS Value Calculator - developed by Dr. Dean Koehler, Vita Plus Corporation, Madison, WI (Sep. 2002).

Diet formulation methods

Further complicating the issue of variability in DDGS nutrient content and digestibility, variability, diet formulation methods can vary among nutritionists. Furthermore, several different diet formulation approaches vary among ruminant, swine, poultry, and fish nutritionists. Over the years, formulation methods have improved from formulating monogastric diets on a crude protein basis to a standardized ileal digestible basis and from digestible energy to net energy systems. These advances in formulation technique have greatly increased our ability to meet the animal's true nutrient requirements.

Diet formulation method affects animal performance and DDGS value and usage. Energy, protein (amino acids), and phosphorus are the 3 most expensive nutrients provided in animal feeds. As a result, diets are formulated to minimize the amounts of these nutrients in the diet to minimize cost, but yet provide adequate levels to insure that animal health and performance is not compromised.

It is well accepted that digestible energy (DE) is a more accurate measure of the utilizable energy in a feed than gross energy. Likewise, metabolizable energy (ME) is a more accurate measure than DE, and net energy (NE) is a better measure than ME. However, depending on the accuracy and availability of DE, ME, or NE values for feed ingredients, level of technological understanding of nutritionists, and knowledge and acceptance of energy requirements using any of these energy systems, diet formulations can vary substantially. Unfortunately, NE values for DDGS are not well defined, but ME and DE values have been well established, but are variable.

Crude protein is really a measure of the nitrogen content of a feed or feed ingredient and does not adequately reflect the amino acid content. While crude protein is an acceptable measure when formulating ruminant diets, it is unacceptable to achieve accuracy in meeting the amino acid needs of pigs, poultry, and fish. This is because the microorganisms in the rumen can convert various forms of nitrogen into the required amounts of microbial protein, with the proper amino acid content, to meet the amino acid needs of ruminants. The digestive systems of monogastric animals do not have these capabilities, and therefore, require specific amounts of digestible amino acids in their daily diet. For monogastrics, formulating diets on a total amino acid basis is more accurate than using crude protein, but greater accuracy is achieved when swine and poultry diets are formulated on a digestible amino acid basis. In addition, it is important to monitor and adjust methionine, threonine, tryptophan, and arginine (poultry) concentrations relative to lysine to insure proper amino acid balance in DDGS diets. It is also important to insure that the proper proportion of energy is provided relative to amino acid levels (e.g. kcal/g lysine). Using a digestible amino acid diet formulation system avoids overfeeding protein and amino acids, minimizes diet cost and nitrogen excretion in the manure.

Similarly, monogastric diets containing DDGS should be formulated on a digestible or available phosphorus basis instead of a total phosphorus basis. By accounting for the relatively high level of available phosphorus in DDGS, the amount of inorganic phosphate supplementation, diet cost, and phosphorus excretion in manure can be substantially reduced. Using a digestible or available phosphorus formulation approach in DDGS diets allows full utilization of the high digestible/available phosphorus content found in DDGS.

To illustrate the impact of diet formulation method on DDGS use based on nutrient variability among sources and formulation method, several examples of swine diets have been formulated for comparison. These relative comparisons also have relevance for other livestock and poultry species using nutrient profiles and formulation methods specific those species, but it is beyond the scope of this paper to give all possible combinations of formulations for various production phases for multiple livestock and poultry species.

Impact of Variation in DDGS Nutrient Content and Digestibility on Dietary DDGS Use in Swine Diets

DDGS metabolizable energy (ME) values

Two extreme values for ME were selected from previously reported data (Pedersen et al., 2007, and Anderson et al., 2009). The maximum ME value for one DDGS source was 4,334 kcal/kg DM while the minimum ME value for a DDGS source was 3,414 kcal/kg DM. Diets were formulated on a standardized true ileal digestible (SID) amino acid basis. The SID levels were based on *in vivo* studies that directly determined the SID amino acid values for specific sources of DDGS. Diets were formulated to contain identical concentrations of ME (**Table 2**). The SID amino acid digestibility coefficients were estimated to be 63%, 82%, 71%, and 69% for lysine, methionine, threonine, and tryptophan, respectively. Desired nutrient levels were based on (NRC, 1998) requirements for a 45 kg pig with 325 g/d of lean tissue gain. Choice white grease was added to the low ME diet at the expense of corn to meet the energy requirement (**Table 2**).

Table 2. Comparison of swine grower diet formulations using high ME (4,334 kcal/kg DM) and low ME (3,414 kcal/kg DM) DDGS sources on diet composition.

Ingredient, kg	High ME DDGS	Low ME DDGS
Corn grain	607.0	569.1
Soybean meal	172.5	172.5
High ME DDGS, 4,336 kcal/kg	200.0	
Low ME DDGS, 3,414 kcal/kg		200.0
Choice white grease		37.9
Limestone	10.0	10.0
Dicalcium phosphate	4.0	4.0
Salt	3.0	3.0
Vitamin/Trace mineral premix	2.0	2.0
L-lysine	1.5	1.5
TOTAL	**1000.0**	**1000.0**

Nutrient	High ME DDGS	Low ME DDGS
Dry matter, %	87.39	84.03
Crude protein, %	19.54	19.22
ME, kcal/kg	3526	3526
Lysine, %	0.83	0.83
Methonine, %	0.30	0.30
Threonine, %	0.59	0.58
Tryptophan, %	0.16	0.16
Calcium, %	0.57	0.57
Total phosphorus, %	0.52	0.51
Available phosphorus, %	0.25	0.25
Ca:P	1.10	1.12

Since the two sources of DDGS greatly vary in ME content, 3.79% choice white grease (pork fat) was added to the low ME DDGS diet to maintain the same level of dietary ME content as the high ME DDGS diet. Without supplementing the diet with choice white grease, the low ME DDGS diet would not meet the pigs' energy requirements. Various supplemental fat sources could be used to provide these deficient calories, but regardless of fat source, the addition of supplemental fat to low ME diets can dramatically increase the total diet cost. These results show that it is important to know the source of DDGS being used and have accurate estimates of the ME, and preferably, the NE content of DDGS and other ingredients to maximize their energy value in diet formulations and minimize diet cost.

Variability in total and digestible lysine concentrations among DDGS sources

As previously described, total and digestible amino acid concentrations also vary among DDGS sources. To show the importance of knowing digestible amino values of the DDGS sources being fed, 3 different diets were formulated to contain 10% DDGS. Sources of DDGS were selected for use in growing swine diet formulations based on their SID lysine values (**Table 3**) obtained from previously published data reported by Urriola (2005). Total lysine content ranged from 0.76% to 1.02% and SID lysine ranged from 0.47% to 0.67%.

Table 3. Total and standardized ileal digestibility (SID) values for lysine, methionine, threonine, and tryptophan among 3 DDGS sources.

Nutrient	Low SID Lysine	Average SID Lysine	High SID Lysine
ME, kcal/kg	3,834	3,893	3,838
Crude protein, %	28.00	29.10	31.90
Lysine, %	0.76	0.85	1.02
Methionine, %	0.50	0.52	0.58
Threonine, %	1.05	1.05	1.15
Tryptophan, %	0.23	0.23	0.28
SID lysine, %	0.47	0.60	0.67
SID methionine, %	0.43	0.50	0.53
SID threonine, %	0.79	0.80	0.87
SID tryptophan, %	0.17	0.20	0.20

Diets were formulated to provide 10% (a low dietary inclusion rate) of each of these 3 DDGS sources to maintain a 0.66% SID dietary lysine level (**Table 4**). Accuracy of SID amino acid values becomes increasingly important as dietary inclusion rates of DDGS increase because DDGS contributes a greater amount of amino acid to the diet relative to the pig's requirement. These results show that while maintaining DDGS at a constant dietary inclusion rate (10%) under this diet formulation scenario, the amount of corn increases and the amount of soybean meal decreases when high SID lysine DDGS is used instead of low SID lysine DDGS, while maintaining diet nutrient content constant. Depending on the relative cost differences between corn, soybean meal, and DDGS, adding high SID lysine DDGS sources to swine diets generally reduces cost/one of complete feed.

Table 4. Diet formulation of swine grower diets using low, average, and high standardized ileal digestibility (SID) lysine values for DDGS.

Ingredient, kg	Low SID Lys. DDGS	Average SID Lys. DDGS	High SID Lys. DDGS
Corn	708.1	713.2	715.9
Soybean meal, 47%	172.7	167.5	164.8
DDGS	100.0	100.0	100.0
Dicalcium phosphate	3.0	3.1	3.2
Limestone	9.7	9.7	9.7
Salt	3.0	3.0	3.0
Vitamin/Trace mineral premix	2.0	2.0	2.0
L-lysine HCL, kg	1.5	1.5	1.5
TOTAL	**1000**	**1000**	**1000**
Nutrient Composition			
Crude protein, %	17.03	16.94	17.11
ME, kcal/kg	3,416	3,422	3,416
Calcium, %	0.50	0.50	0.50
Phosphorus, %	0.45	0.45	0.45
Ca:P	1.11	1.11	1.11
Salt, %	0.36	0.36	0.36
Crude fat, %	4.34	4.26	4.24
Lysine, %	0.90	0.90	0.91
SID lysine, %	0.66	0.66	0.66
Methonine, %	0.29	0.29	0.29
SID methonine, %	0.26	0.26	0.26
Threonine, %	0.63	0.62	0.63
SID threonine, %	0.53	0.52	0.52
Tryptophan, %	0.18	0.17	0.18
SID tryptophan, %	0.15	0.15	0.15

Formulation Methods

Crude protein basis

Several decades ago, most swine diets in the U.S. were formulated on a crude protein basis because total and digestible amino acid requirements were not well established for different stages of production, and total and digestible amino acid content of feed ingredients was not determined. Once knowledge of specific amino acid requirements was well defined, nutritionists began formulating diets on a total amino acid basis. However, amino acid digestibility varies among sources and to account for this, diets currently are formulated in a digestible amino acid basis to provide the highest nutritional and economic value of swine diets as well as achieve optimal performance.

In order to show the potential problems that can occur when formulating swine diets containing DDGS on a crude protein basis, 3 diets were formulated to contain 0, 10, and 20% DDGS to meet the crude protein requirement (16%) of a 50 kg pig (**Table 5**). When formulating the diet to maintain a consistent crude protein level of 16%, a 10% inclusion rate of DDGS will meet all of the pigs' nutrient requirements, including amino acids. However, when the amount of DDGS is increased to 20%, it is impossible to meet the total lysine requirement of 0.75% for a 50 kg pig even though 0.15% of L-lysine HCl is added. If this diet was fed to pigs, growth rate and feed conversion would be reduced compared to feeding the 0 and 10% DDGS diets using this diet formulation approach.

Table 5. Ingredient and nutrient composition of a 16% crude protein swine grower diet containing 0, 10, and 20% DDGS.

Ingredient, kg	0% DDGS	10% DDGS	20% DDGS
Corn	783.5	733.8	684.2
Soybean meal, 47%	196.7	147.1	97.4
DDGS	0.0	100.0	200.0
Dicalcium phosphate	5.1	3.6	2.0
Limestone	8.2	9.0	9.9
Salt	3.0	3.0	3.0
L-lysine HCl	1.5	1.5	1.5
Vitamin/Trace mineral premix	2.0	2.0	2.0
TOTAL	**1000.0**	**1000.0**	**1000.0**
Nutrient Composition			
Crude protein, %	16.0	16.0	16.0
ME, kcal/kg	3,372	3,316	3,261
Lysine, %	0.92	0.82	**0.72**
Methonine, %	0.26	0.27	0.28
Threonine, %	0.59	0.58	0.57
Tryptophan, %	0.18	0.16	0.15
Calcium, %	0.50	0.50	0.50
Phosphorus, %	0.45	0.45	0.45
Ca:P	1.11	1.11	1.11
Salt, %	0.37	0.41	0.44
Crude fat, %	3.65	4.14	4.64

Total amino acid basis

To demonstrate the problems that can occur when formulating diets on a total amino acid basis for swine, 4 example DDGS diets (0, 10%, 20% and 205 with added synthetic amino acids) were formulated on a total amino acid basis (**Table 6**). Diets were formulated using nutrients required for a 50 kg growing pig.

Although NRC requirements for total lysine, methionine, threonine, and tryptophan were met (in some cases exceeded) in each of the diets, digestibility of the amino acids was not considered. As a result, the SID amino acid requirements for lysine and tryptophan were not met in either the 10% or 20% DDGS diets (**Table 6**). However, when the 20% DDGS diet was supplemented with synthetic L-tryptophan and more soybean meal (adjusted 20% DDGS), both the SID lysine and SID tryptophan requirements are met.

Table 6. Ingredient and nutrient composition of a swine grower diet containing 0, 10, and 20% DDGS and formulated on a total lysine basis.

Ingredient, kg	0% DDGS	10% DDGS	20% DDGS	Adjusted 20% DDGS
Corn	796.5	757.5	635.4	610.9
Soybean meal, 47%	183.4	123.0	147.1	170.3
DDGS	0.0	100.0	200.0	200.0
Dicalcium phosphate	5.4	4.1	0.9	0.9
Limestone	8.1	9.0	10.0	9.9
Salt	3.0	3.0	3.0	3.0
Vitamin/Trace mineral premix	2.0	2.0	2.0	2.0
L-lysine HCl	1.5	1.5	1.5	1.5
L-tryptophan	0.0	0.0	0.0	1.5
TOTAL	**1000.0**	**1000.0**	**1000.0**	**1000.0**
Nutrient Composition				
Crude protein, %	15.5	15.1	18.0	19.0
ME, kcal/kg	3,372	3,316	3,262	3,281
Lysine, %	0.88	0.75	0.85	0.92
Methonine, %	0.26	0.26	0.31	0.32
Threonine, %	0.57	0.54	0.64	0.83
Tryptophan, %	0.17	0.15	0.18	0.20
Calcium, %	0.50	0.50	0.50	0.50
Phosphorus, %	0.45	0.45	0.45	0.46
Ca:P	1.11	1.11	1.11	1.09
Salt, %	0.37	0.41	0.44	0.44
Crude fat, %	3.66	4.16	4.60	4.57
SID lysine, %	0.66	**0.52**	**0.60**	0.66

SID methonine, %	0.23	0.23	0.26	0.27
SID threonine, %	0.49	0.44	0.51	0.54
SID tryptophan, %	0.15	**0.11**	**0.12**	0.13

True ileal digestibility basis

Currently, most swine diets in the U.S. are formulated on a SID amino acid basis. This formulation method provides high accuracy in meeting the nutrient needs of pigs and allows nutritionists to use high dietary inclusion rates (>10%) of DDGS, if amino acid digestibility values are known for the source being fed, without compromising pig performance. As shown in **Table 7**, diets formulated on a SID basis containing up to 30% DDGS, all meet the SID lysine level of 0.66% for a 50 kg pig, and meet all other nutrient requirements including SID methionine, threonine, and tryptophan. Note that no additional synthetic amino acids were used in these diets beyond a constant inclusion rate of 0.15% L-lysine HCl. These results show that in order to insure excellent pig performance, even when adding DDGS up to 30% of the diet, diets must be formulated on a SID amino acid basis to insure that digestible amino acid requirements are met.

Table 7. Ingredient and nutrient composition of a swine grower diet containing 0, 10, 20, and 30% DDGS and formulated on a standardized ileal digestible (SID) lysine basis.

Ingredient, kg	0% DDGS	10% DDGS	20% DDGS	30% DDGS
Corn	795.9	746.3	672.1	586.4
Soybean meal, 47%	184.0	134.4	109.8	96.6
DDGS	0.0	100.0	200.0	300.0
Dicalcium phosphate	5.4	3.9	1.7	0.0
Limestone	8.2	9.0	9.9	10.5
Salt	3.0	3.0	3.0	3.0
Vitamin/Trace mineral premix	2.0	2.0	2.0	2.0
L-lysine HCl	1.5	1.5	1.5	1.5
TOTAL	**1000.0**	**1000.0**	**1000.0**	**1000.0**
Nutrient Composition				
Crude protein, %	15.48	17.17	18.86	20.55
ME, kcal/kg	3371	3317	3262	3205
Calcium, %	0.50	0.50	0.50	0.50
Phosphorus, %	0.45	0.45	0.45	0.49
Ca:P	1.11	1.11	1.11	1.02
Salt, %	0.37	0.41	0.44	0.48
Crude fat, %	3.66	4.54	4.58	5.04
Lysine, %	0.88	0.90	0.92	0.94
SID lysine, %	0.66	0.66	0.66	0.66
Methonine, %	0.26	0.29	0.32	0.35
SID methonine, %	0.23	0.25	0.27	0.29
Threonine, %	0.57	0.63	0.68	0.74
SID threonine, %	0.48	0.51	0.54	0.57

Tryptophan, %	0.17	0.18	0.2	0.21
SID tryptophan, %	0.15	0.14	0.13	0.12

Supplemental synthetic amino acids and reduction in soybean meal use

The addition of synthetic (crystalline) amino acids to the diet has several advantages. It reduces excess nitrogen (protein), by reducing the amount of soybean meal or other high protein ingredients in the diet, while meeting the amino acid requirements of pigs and supporting excellent performance. It also minimizes nitrogen excretion and ammonia emissions from manure, and can significantly reduce total diet cost, especially when soybean meal is expensive. With increased commercial availability of crystalline lysine, methionine, threonine, and tryptophan at reasonable prices, a significant amount of soybean meal can be removed from the diet, while meeting the amino acid requirements for the first four limiting amino acids (lysine methionine, threonine, and tryptophan), as long as they are formulated on a SID amino acid basis.

The level of soybean meal used in the 30% DDGS diet containing reduced soybean meal in **Table 8**, was determined by adding enough soybean meal to the diet to prevent the next (fifth) limiting amino acid (isoleucine) from becoming deficient. Diets were formulated to meet or exceed all NRC (1998) recommendations for 45 kg pigs, and on a SID amino acid basis.

One of the challenges of feeding diets containing high amounts (>20%) of DDGS is the excessive amount of crude protein (nitrogen) it provides, due to its relatively poor crude protein:lysine ratio. If the crude protein level is too high, it can reduce growth performance because of the energetic cost of eliminating excess nitrogen from the pig's body. By adding synthetic amino acid to DDGS diets, the amount of excess protein is reduced. In fact, by reducing soybean meal use to only 2% of the diet and adding enough synthetic amino acids to meet the pig's requirement, crude protein level was below a typical corn-soybean meal diet (**Table 8**).

Table 8. Ingredient and nutrient composition of a diet containing 30% DDGS, high amounts of synthetic amino acids, and reduced soybean meal.

Ingredient, kg	Control	Reduced Soybean Meal, 30% DDGS, and Synthetic Amino Acids
Corn	738.5	653.1
Soybean meal	238.8	20.0
DDGS	0.0	300.0
Limestone	8.2	12.0
Dicalcium phosphate	8.0	2.6
Salt	3.0	3.0
Premix	2.0	2.0
L-Lysine	1.5	5.9
L-Threonine	0.0	0.7
DL-Methionine	0.0	0.0
L-Tryptophan	0.0	0.7
TOTAL	**1000.0**	**1000.0**
Nutrient Composition		
Crude protein, %	17.6	16.3
ME, kcal/kg	3,333	3,459
SID lysine, %	0.92	0.84
SID methonine, %	0.26	0.26
SID threonine, %	0.56	0.52
SID tryptophan, %	0.18	0.17
SID isoleucine. %	0.61	0.46
Calcium, %	0.60	0.58
Total phosphorus, %	0.52	0.48
Available phosphorus, %	0.21	0.26
Ca:P	1.15	1.20

Conclusions

In order to achieve the best economic and nutritional value from DDGS, the source, nutrient content, and digestibility must be known. Depending on the nutrient composition of the DDGS source being used, and the diet formulation methods chosen, the relative economic and nutritional value of DDGS can vary substantially. Using accurate energy, amino acid, and phosphorus digestibility values for DDGS can reduce excessive feeding of nutrients, avoid nutrient deficiencies, and reduce diet costs while supporting optimal animal performance.

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