Value and use of 'new generation' distiller's dried grains with solubles in swine diets

JERRY SHURSON, MINDY SPIEHS, JENNIFER WILSON AND MARK WHITNEY

Department of Animal Science, University of Minnesota, St. Paul, Minnesota

What is DDGS?

Corn distiller's dried grains with solubles (DDGS) is a co-product produced by dry mill ethanol plants as a result of fermenting corn starch to produce fuel ethanol and carbon dioxide. Each bushel of corn (25.4 kg) fermented in a dry mill ethanol plant will produce approximately 10.2 liters of ethanol, 8.2 kg of carbon dioxide, and 8.2 kg of DDGS. Yellow dent corn is most commonly used to produce ethanol and DDGS because it is an excellent source of readily fermentable starch. Corn contains about 62% starch, 3.8% corn oil, 8.0% protein, and 11.2% fiber, and 15% moisture. Because most of the starch is converted to ethanol during fermentation, the resulting nutrient fractions (protein, oil, fiber) are 2 to 3 times more concentrated in DDGS compared to corn. A few ethanol plants use sorghum, barley, and wheat to make ethanol, and as a result, the nutritional composition of the DDGS produced from these grain sources is different than corn DDGS.

Approximately 40% of US fuel ethanol is produced in dry mills, whereas the other 60% is produced in wet mills (Figures 1 and 2). Because the ethanol production processes are different between dry mills and wet mills, the resulting corn co-products are also nutritionally different. Dry mills produce DDGS, but wet mills produce corn gluten feed, corn gluten meal, and corn germ meal. According to Long (1985), wet milling of yellow dent corn involves its separation into the four major products (dry matter basis): corn starch (67.2 %), corn gluten feed (19.6 %), corn gluten meal (60% protein, 5.7 %), and corn germ (50% corn oil, 7.5 %).

The ethanol beverage industry also produces DDGS (<1% of total DDGS production), but it is often dark in color, tends to be more variable in nutrient content (due to the type and source of grain used), and has lower levels of digestible nutrients than DDGS from 'new generation' fuel ethanol plants. Brewer's dried grain is a co-product of the beer manufacturing industry and consists of the dried residue of barley malt and other grains that have been used to provide maltose and dextrins for fermenting. Use of brewer's dried grains in monogastric diets is limited due to the relatively high fiber level (18 to 19%). A comparison of the nutrient composition of these grain co-products is shown in Table 1.

The primary nutritional advantages of new generation DDGS compared to corn gluten feed, corn gluten meal, and brewer's dried grains are the high levels of oil and available phosphorus (Table 1). The DE and ME value of new generation DDGS is significantly higher than corn gluten feed and brewer's dried grains, comparable to corn, but less than corn gluten meal. Amino acid levels of DDGS are lower than corn gluten meal and corn germ meal, but comparable to corn gluten feed and brewer's dried grains.

How is 'new generation' DDGS different from 'old generation' DDGS?

Research conducted at the University of Minnesota has shown that DDGS produced in new generation, modern ethanol plants is higher in digestible and metabolizable energy, higher in digestible amino acids, and higher in available phosphorus than DDGS produced in older, more traditional ethanol plants. Although DDGS contains a significant amount of crude fiber (7 to 8%), it also contains a

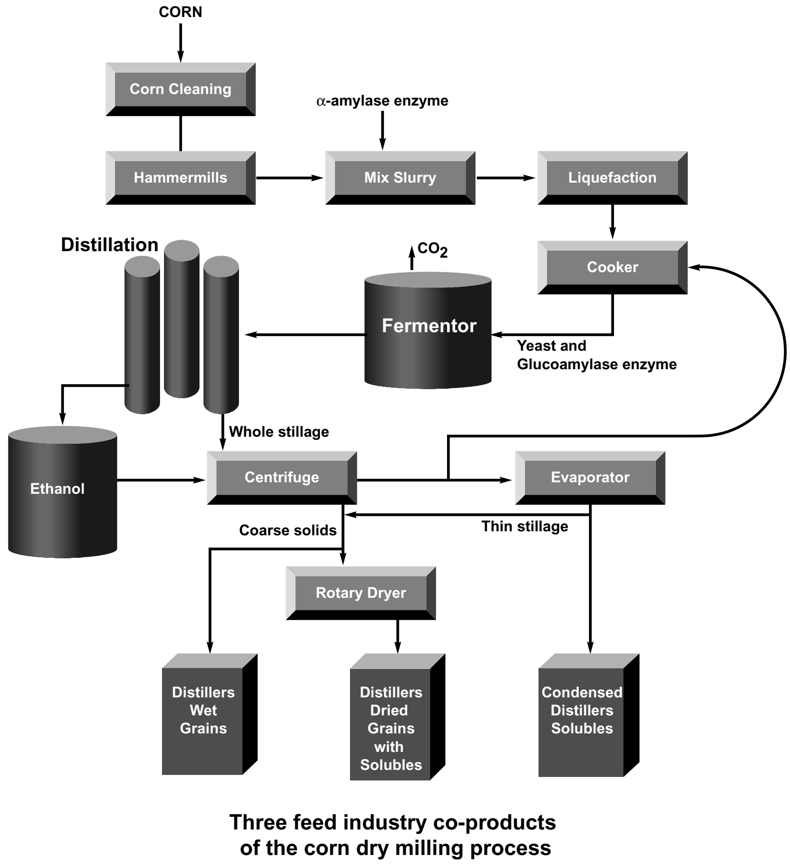

Figure 1. Dry mill production of ethanol.

Table 1. Nutrient composition comparison (as fed basis) between new generation DDGS, corn gluten feed, corn gluten meal, corn germ meal, and brewer's dried grains.

	New generation DDGS	Corn gluten feed[1] (NRC, 1998)	Corn gluten meal[1] (NRC, 1998)	Corn germ meal (Feedstuffs, 2001)	Brewer's dried grains (NRC, 1998)
Dry matter, %	89	90	90	90	92
Crude protein, %	27.2	21.5	60.2	20.0	26.5
Crude fat, %	9.5	3.0	2.9	1.0	7.3
ADF, %	14.0	10.7	4.6	No data	21.9
NDF, %	38.8	33.3	8.7	No data	48.7
DE, kcal/kg	3529	2990	4225	No data	2100
ME, kcal/kg	3197	2605	3830	2900	1960
Arginine, %	1.06	1.04	1.93	1.3	1.53
Histidine, %	0.68	0.67	1.28	0.7	0.53
Isoleucine, %	1.01	0.66	2.48	0.7	1.02
Leucine, %	3.18	1.96	10.19	1.7	2.08
Lysine, %	0.74	0.63	1.02	0.9	1.08
Methionine, %	0.49	0.35	1.43	0.6	0.45
Cystine, %	0.52	0.46	1.09	0.4	0.49
Phenylalanine, %	1.32	0.76	3.84	0.9	1.22
Threonine, %	1.01	0.74	2.08	1.1	0.95
Tryptophan, %	0.21	0.07	0.31	0.2	0.26
Valine, %	1.34	1.01	2.79	1.2	1.26
Calcium, %	0.05	0.22	0.05	0.30	0.32
Phosphorus, %	0.79	0.83	0.44	0.50	0.56
Available phosphorus, %	0.71	0.49	0.07	0.15	0.19

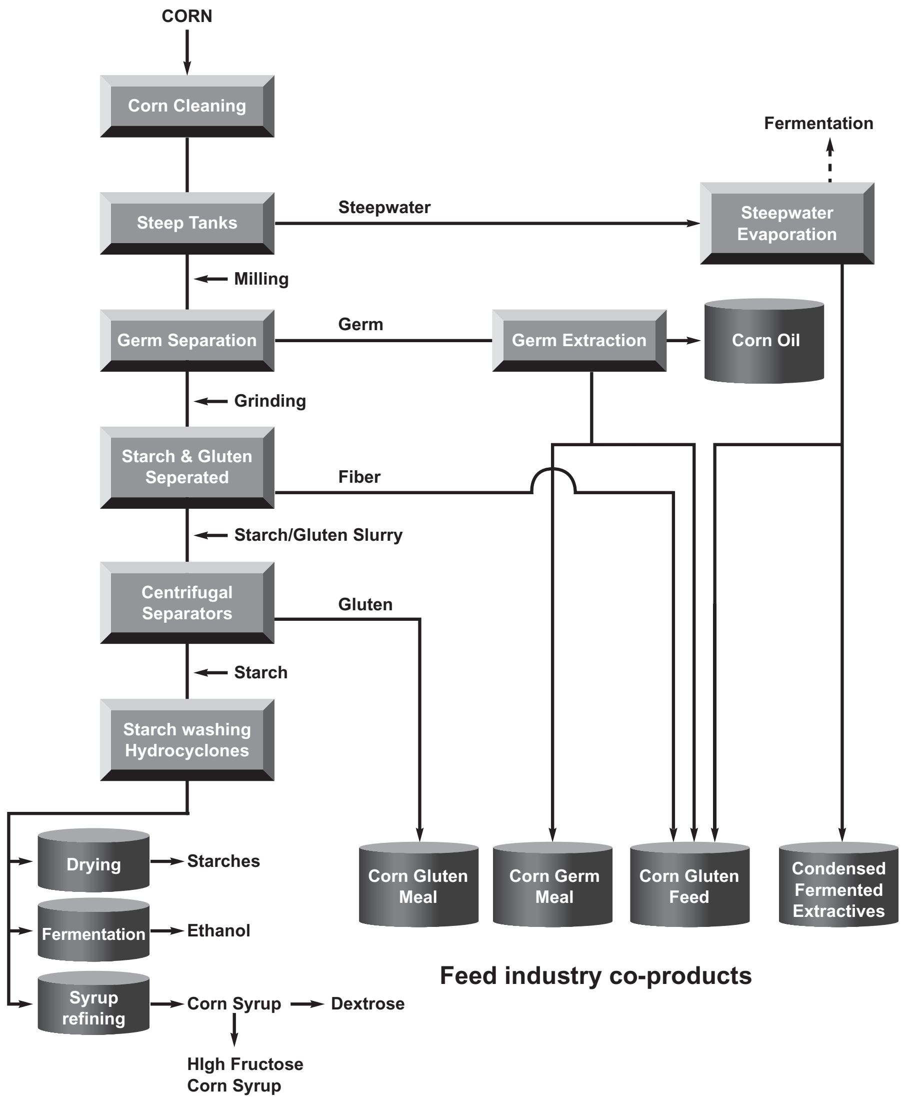

Figure 2. The corn wet-milling process.

high amount of crude fat (9 to 10% on an as fed basis), which results in DDGS containing an energy value (DE, 3965 kcal/kg; ME, 3592 kcal/kg) about equal to that found in corn (DE, 3961 kcal/kg; ME, 3843 kcal/kg) on a dry matter basis (Table 2).

Additional studies conducted at the University of Minnesota have shown that the 'golden' colored DDGS produced in new generation ethanol plants contains significantly higher levels of amino acids (Table 3). Furthermore, the level of apparent digestible amino acids in new generation DDGS is higher than values from dark colored, 'old generation' DDGS and values published in NRC (1998) shown in Table 4.

Perhaps the biggest nutritional advantage of feeding DDGS to swine is its high available phosphorus content. It is well known that corn is relatively low in phosphorus (0.28%), and relative phosphorus availability is also low (14%). However, the phosphorus content of new generation DDGS is 0.89% and the relative availability of phosphorus is increased to 90% after the corn has gone through the fermentation process (Table 5).

Why is there so much interest in feeding DDGS to swine?

One of the hottest topics in the feed industry today involves feeding new generation distiller's dried grains with solubles (DDGS) to swine. Historically, distiller's dried grains with solubles (DDGS) have

Table 2. Comparison of energy values for DDGS (dry matter basis).

	New DDGS (Calculated)	New DDGS (Trial average)	Old DDGS (Calculated)	DDGS (NRC, 1998)
DE, kcal/kg	3965	4011	3874	3449
ME, kcal/kg	3592	3827	3521	3038

Corn: DE (kcal/kg) = 3961, ME (kcal/kg) = 3843

Table 3. Comparison of amino acid composition of DDGS (dry matter basis) between new generation DDGS, old generation DDGS, and values published in NRC (1998)[1].

	New generation DDGS	Old generation DDGS	DDGS NRC (1998)
Arginine, %	1.20 (9.1)	0.92 (18.7)	1.22
Histidine, %	0.76 (7.8)	0.61 (15.2)	0.74
Isoleucine, %	1.12 (8.7)	1.00 (9.1)	1.11
Leucine, %	3.55 (6.4)	2.97 (12.4)	2.76
Lysine, %	0.85 (17.3)	0.53 (26.5)	0.67
Methionine, %	0.55 (13.6)	0.50 (4.5)	0.54
Phenylalanine, %	1.47 (6.6)	1.27 (8.1)	1.44
Threonine, %	1.13 (6.4)	0.98 (7.3)	1.01
Tryptophan, %	0.25 (6.7)	0.19 (19.8)	0.27
Valine, %	1.50 (7.2)	1.39 (2.3)	1.40

[1]Values in parentheses are coefficients of variation among ethanol plants.

Table 4. Comparison of apparent ileal digestible amino acid composition of DDGS (dry matter basis) between new generation DDGS, old generation DDGS, and values published in NRC (1998).

	New generation DDGS	Old generation DDGS	DDGS NRC (1998)
Arginine, %	0.90	0.60	0.88
Histidine, %	0.51	0.30	0.45
Isoleucine, %	0.72	0.42	0.73
Leucine, %	2.57	1.84	2.10
Lysine, %	0.44	0.00	0.31
Methionine, %	0.32	0.24	0.39
Phenylalanine, %	0.89	0.68	1.09
Threonine, %	0.62	0.36	0.56
Tryptophan, %	0.15	0.15	0.14
Valine, %	0.92	0.51	0.88

Table 5. Comparison of phosphorus level and relative availability of DDGS and corn (dry matter basis).

	New DDGS	Old DDGS	DDGS (NRC, 1998)	Corn (NRC, 1998)
Total P, %	0.89	0.90	0.83	0.28
Relative P availability, %	90.00	No data	77.00	14.00
Available P, %	0.80	No data	0.64	0.04

not been used extensively in swine diets. The primary reasons for this limited use include variability in quality and nutrient content among sources, poor amino acid digestibility due to overheating during drying, concerns about the high fiber content, and cost competitiveness with corn, soybean meal and dicalcium phosphate. Although the majority (>80%) of DDGS has historically been fed to cattle, recent research studies conducted at the University of Minnesota have clearly shown that corn DDGS produced by new generation ethanol plants contains significantly higher levels of digestible and metabolizable energy, digestible amino acids, and available phosphorus than found in DDGS produced by older, more traditional ethanol plants. Because of its higher nutrient value, new generation DDGS is well suited for swine and poultry diets, and can be a cost effective partial replacement for corn, soybean meal, and dicalcium phosphate in swine feeding programs.

As a result of recent research conducted at the University of Minnesota, usage of new generation DDGS in US swine feeding programs has increased from about 30,000 tonnes in 2000 to more than 80,000 tonnes in 2002. The production of ethanol and DDGS is increasing at a rapid rate, which is due in part to the banning of MTBE (methyl tertiary butyl ether) as an oxygenation agent in gasoline in 14 states, and the resulting increase in demand for ethanol to be used as a replacement for MTBE. Currently, the US fuel ethanol industry produces about 3.8 million tonnes of DDGS. By 2005, this amount is projected to be near 5.5 million tonnes. New and undeveloped markets are needed to utilize this increased DDGS supply. The pork industry is a very viable, but underdeveloped DDGS market that could realize substantial economic benefits from using new generation DDGS.

What are the recommended maximum inclusion rates of DDGS in swine diets?

Based upon research studies we have conducted at the University of Minnesota, our current recommendations for maximum usage rate of DDGS in swine diets are as follows:

Production phase	Maximum % of diet
Nursery pigs (>7 kg)	25
Grow-finish pigs	20
Developing gilts	20
Gestating sows	50
Lactating sows	20
Boars	50

These recommendations assume that high quality DDGS is free of mycotoxins and diets are formulated on a digestible amino acid and available phosphorus basis. Currently in most commercial swine operations in the US, nutritionists are adding 10% DDGS to grow-finish, gestation and lactation diets, and 5% DDGS in starter diets with excellent success.

We conducted two nursery trials using pigs weighing 7.1 kg (Experiment 1) and 5.3 kg (Experiment 2) and fed phase 2 (day 4-17 postweaning) and phase 3 (day 18 to postweaning) nursery diets containing up to 25% DDGS formulated on a digestible amino acid basis and equivalent levels of total calcium and total phosphorus. Results of these two experiments show that up to 25% DDGS can be included in nursery diets without any negative effects on growth performance (Figure 3) but increasing amounts of DDGS in the diet of pigs weighing less than 7 kg in body weight may result in a slight reduction in performance during phase 2 but not during phase 3 (Figure 4).

Similarly, grow-finish and gilt development diets containing levels up to 30% DDGS should provide equivalent growth performance compared to pigs fed corn-soybean meal diets if they are formulated on a digestible amino acid and available phosphorus basis. However, due to concerns of reduced belly firmness and soft pork fat at high levels of DDGS inclusion, we recommend no more than 20% DDGS be added to late finishing diets when the rate of fat deposition is highest.

In a recent study we conducted at the University of Minnesota, iodine number increased linearly ($P<0.05$), and carcass fat became more unsaturated, as the level of DDGS was increased in grow-finish diets (Table 6). It has been well established that feeding diets that contain an unsaturated fat source can alter the level of saturation in pork fat. Lea *et al.* (1970) characterized quality pork fat as having an iodine number below 70. In our study, iodine values were slightly above 70 (70.6 and 72 for diets containing 20 and 30% DDGS, respectively). Overall, our values were within the upper range (50 to 72) of iodine numbers reported for pork belly fat in swine fed raw soybeans (Pontif *et al.*, 1987) or barley- and maize-based diets (Lucas *et al.*, 1960; Lawrence, 1974). The effect of DDGS feeding on iodine number was reflected in the analysis of belly firmness score (Table 6). Belly firmness scores indicated that bellies from pigs that were fed 30% DDGS were softer ($P<0.05$) than bellies from pigs fed 0 or 20% DDGS diets. Softer bellies were most likely a consequence of elevated levels of unsaturated lipids provided by DDGS in the diets.

We conducted an experiment where 93 sows were fed diets containing either 0 or 50% DDGS during gestation and 0 or 20% DDGS in lactation through the first reproductive cycle and 49 of these sows remained on their respective dietary

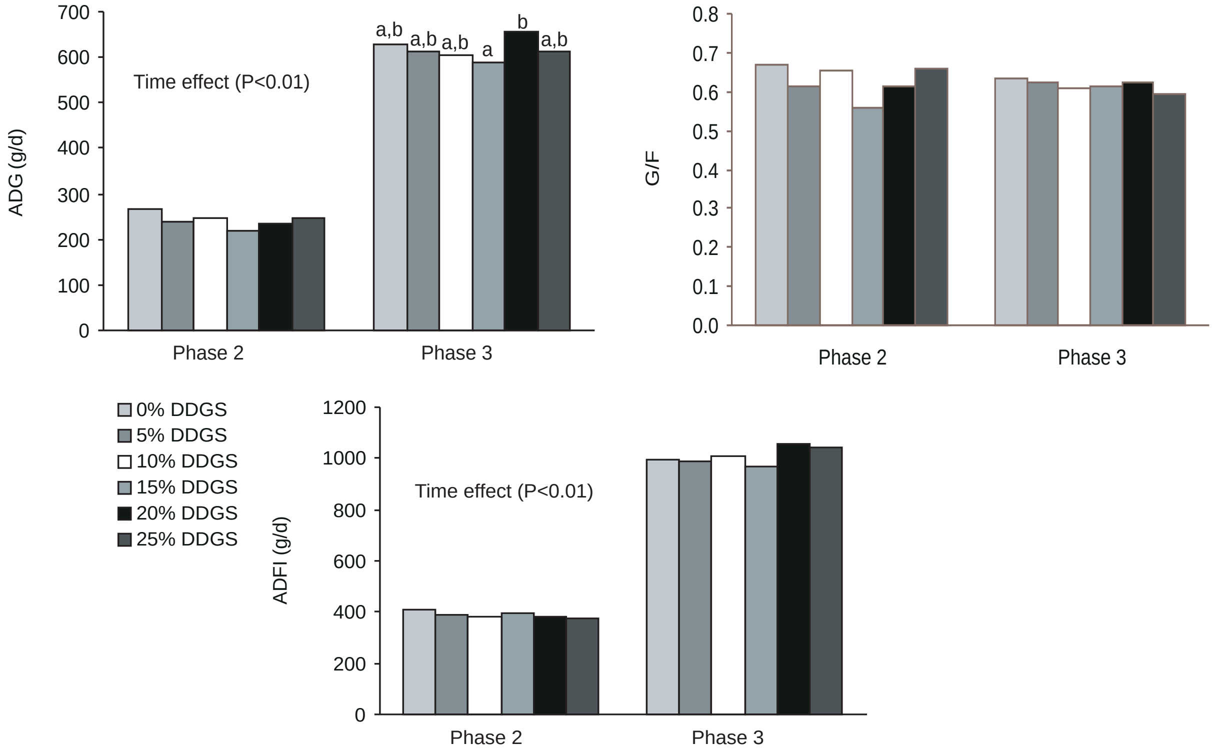

Figure 3. Effect of dietary DDGS level on growth performance, feed efficiency, and feed intake of nursery pigs (Experiment 1). Means not sharing a common superscript letter within each time period are significantly different (P<0.05). Phase 2 and 3 CV values were 14.2 and 7.0, 11.9 and 8.4, and 18.1 and 10.0 for average daily gain, average daily feed intake and gain:feed, respectively.

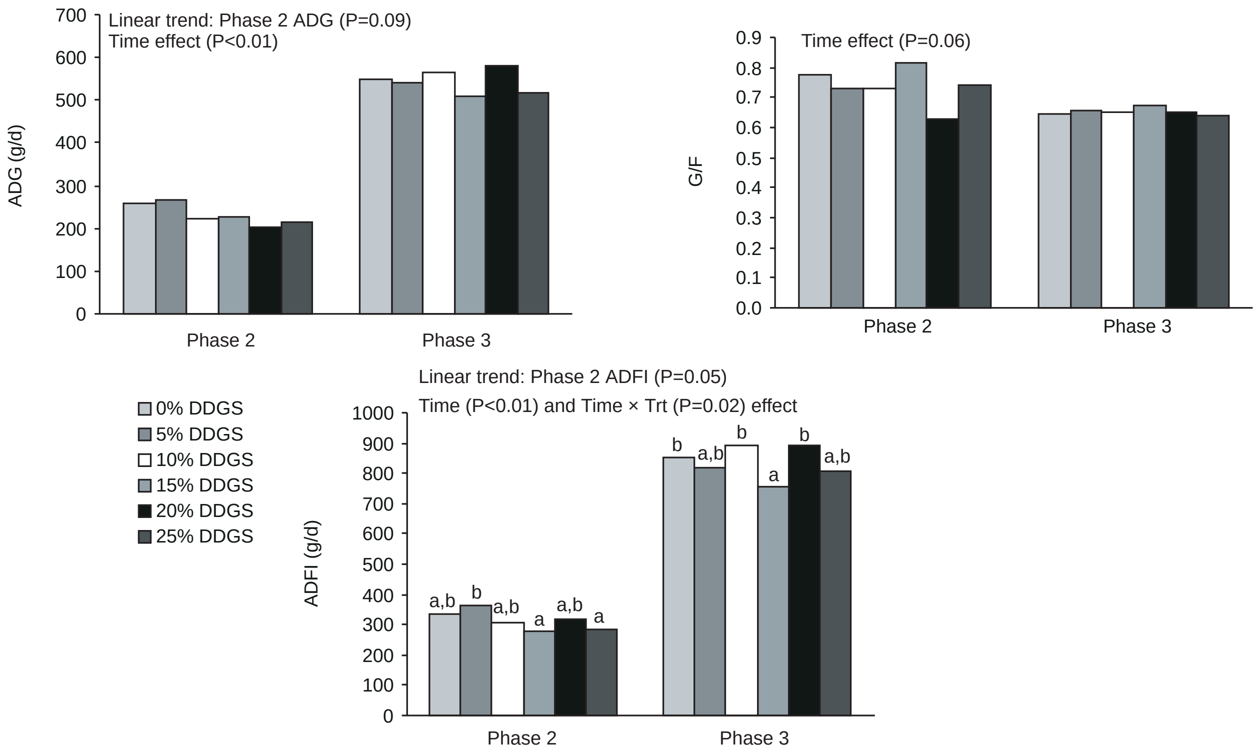

Figure 4. Effect of dietary DDGS level on growth performance, feed efficiency, and feed intake of nursery pigs (Experiment 2). Means not sharing a common superscript letter within each time period are significantly different (P<0.05). Phase 2 and 3 CV values were 24.4 and 9.4, 12.0 and 6.8, and 17.5 and 5.7 for average daily gain, average daily feed intake and gain:feed, respectively.

Table 6. Fat quality characteristics of market pigs fed diets containing 0 to 30% DDGS.

	Dietary treatment (% DDGS)				
	Control	10%	20%	30%	RMSE
Belly thickness, cm	3.15[c]	3.00[cd]	2.84[cd]	2.71[d]	0.56
Belly firmness score[a], degrees	27.3[c]	24.4[cd]	25.1[c]	21.3[d]	6.3
Adjusted belly firmness score[b], degrees	25.9[c]	23.8[cd]	25.4[c]	22.4[d]	5.4
Iodine number	66.8[c]	68.6[d]	70.6[e]	72.0[e]	3.4

[a]Belly firmness score = $\cos^{-1}[(0.5(L^2) - D^2)/(0.5(L^2))]$, where L = belly length measured on a flat surface and D = the distance between the two ends of a suspended belly; higher belly firmness scores indicate firmer bellies.
[b]Belly firmness score adjusted for belly thickness.
[c,d,e]Means within a row lacking a common superscript letter differ (P<0.05).

treatments for a second reproductive cycle. Sows fed the DDGS diets weaned more pigs per litter during the second reproductive cycle compared to sows fed the control corn-soybean meal diets (Figure 5). This response is similar to the litter size response observed in other studies where sows are fed high fiber diets. It is unknown if this response can be obtained when feeding diets containing lower levels of DDGS. Based upon these results, up to 50% DDGS can be used effectively in gestation diets and up to 20% can be used in lactation diets when diets are formulated on a digestible amino acid basis and no mycotoxins are present in DDGS. However, when switching sows from a corn-soybean meal diet to diets containing high amounts of DDGS in gestation or lactation, feed consumption will be reduced for approximately 5 to 7 days until they adjust to diets containing DDGS. This is a significant issue during lactation when our goal is to maximize feed (energy intake) (Figure 6). We know from experience that this effect does not occur when 10% DDGS is added to lactation and gestation diets. If high amounts of DDGS are to be fed during gestation, formulate diets to contain 10% DDGS and then increase DDGS inclusion level when each new batch of feed is made to allow the sows to adapt to the DDGS diet and avoid reduced feed intake. If high amounts are to be fed during lactation (>10%), feed gestation diets containing at least 20% DDGS at least one week prior to farrowing or increase the DDGS level in lactation diets after the first week of lactation.

How should I formulate diets containing DDGS to obtain optimal performance and value?

Our research results have shown that energy and amino acid digestibility, as well as phosphorus

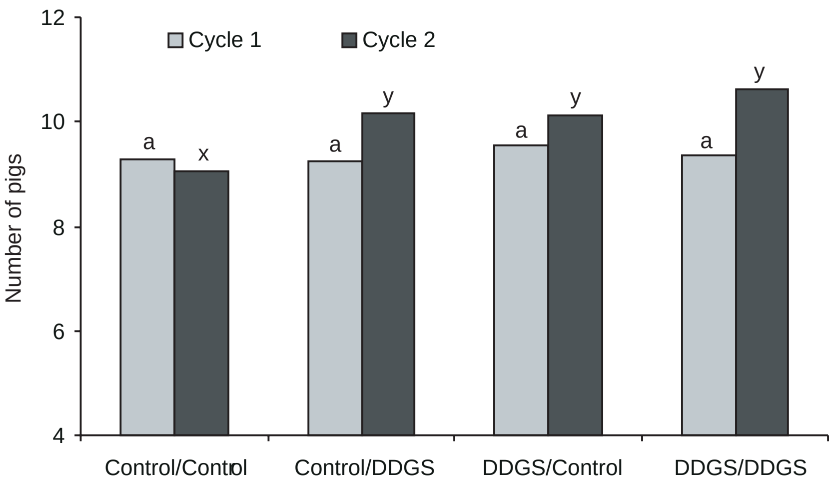

Figure 5. Effect of feeding gestation diets containing 0 or 50% DDGS and lactation diets containing 0 or 20% DDGS on the number of pigs weaned/litter during two reproductive cycles (Within cycle, values with different letters differ, P<0.10).

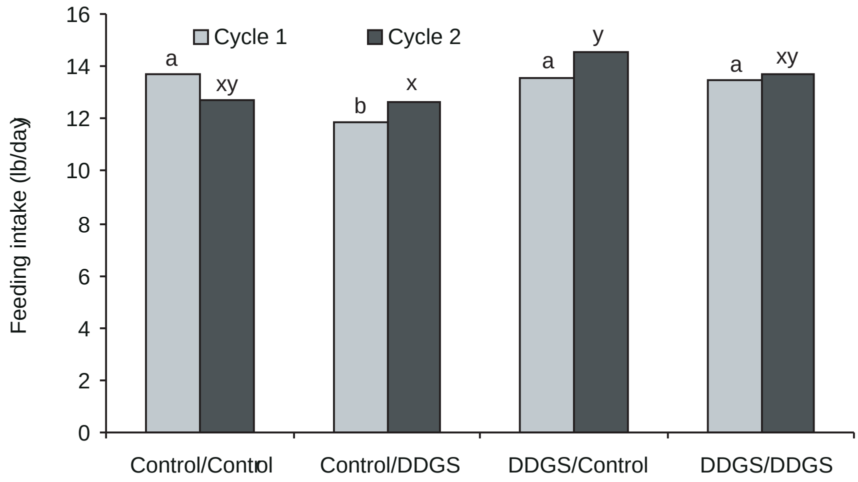

Figure 6. Effect of feeding gestation diets containing 0 or 50% DDGS and lactation diets containing 0 or 20% DDGS on average daily lactation feed intake during two reproductive cycles (Within cycle, values with different letters differ, P<0.10).

availability of DDGS produced in Minnesota and South Dakota ethanol plants, is higher than nearly all of the values reported in NRC (1998) and values we obtained from evaluating low quality DDGS. Our apparent digestible amino acid and available phosphorus nutrient values should be used to formulate practical diets for all phases of production to ensure that the maximum nutritional value of DDGS is obtained, and that optimal performance is achieved, particularly when adding more than 10% DDGS to any swine diet. Formulating diets using total amino acid and phosphorus values may provide acceptable performance at low inclusion rates (<10%) of DDGS in swine diets, but not at higher inclusion rates.

Is DDGS an economical feed ingredient?

Depending on the prices of competing feed ingredients (e.g. corn, soybean meal, and dicalcium phosphate), DDGS will usually reduce feed costs. In one ton of complete feed, adding 200 lbs of new generation DDGS (and 3 lbs of limestone) to a finisher diet will replace approximately:

177 lbs of corn
20 lbs of soybean meal 44%
6 lbs of dicalcium phosphate

Calculate the opportunity cost of using new generation DDGS in swine diets as follows:

Additions:				
DDGS	200 lbs	x	price/lb	= $
Limestone	3 lbs		price/lb	= $
			Total A	**= $**
Subtractions:				
Corn	177 lbs	x	price/lb	= $
Soybean meal 44%	20 lbs	x	price/lb	= $
Dicalcium phosphate	6 lbs	x	price/lb	= $
			Total S	**= $**

Opportunity cost:

Total S – Total A = Opportunity cost of DDGS/lb x 200 lbs/ton = Opportunity cost/ton of complete feed

Is the cost saving different if DDGS diets are formulated on a total vs. digestible amino acid basis?

The method used to formulate DDGS diets will affect the economic value of DDGS in swine diets. Many nutritionists formulate corn/soybean meal-based swine diets to achieve a desired level of total lysine and total phosphorus. Using this approach, adding 200 lbs of DDGS to a typical early grower diet (1486 kcal ME/lb, 1.0% lysine, 0.55% P) will replace 162 lbs of corn, 36 lbs of soybean meal 44%, and 5 lbs of dicalcium phosphate (Table 3). Based upon the prices shown in Table 7, this would result in a feed cost savings of $1.40/ton of complete feed compared to feeding a typical corn/soybean meal diet with 3 lbs of synthetic lysine added. Under this scenario, you could afford to pay an additional $14/ton for DDGS ($99/ton) and break even with the cost of the typical diet.

If a 10% DDGS diet is formulated on an apparent digestible amino acid basis using amino acid and available phosphorus values obtained from University of Minnesota research, more corn (177 lbs), less soybean meal (19 lbs), and more dicalcium phosphate (7 lbs) is replaced compared to formulating DDGS diets on a total lysine and phosphorus basis. The net result is that because more corn ($3.57/cwt) and less soybean meal ($9.50/cwt) is being replaced by DDGS, the cost savings is reduced to $0.62/ton compared to the typical corn/soybean meal diet used in this comparison. This means that you could afford to pay an additional $6.20/ton for DDGS ($91.20) and break even with the cost of the typical diet.

How variable is DDGS nutrient content and digestibility?

Historically, grain co-products like DDGS have been treated as commodities in the marketplace. However, like all co-products, there is large variation in the quality of DDGS available for livestock feeds. Cromwell *et al.* (1993) conducted a study to compare physical, chemical and nutritional characteristics of nine different sources of DDGS for chicks and pigs. The color of these sources ranged from very light to very dark, and odor ranged from a sweet smell to smoky or burnt smell. There was also a wide range in nutrient concentration among DDGS sources. Ranges in nutrient concentration of selected nutrients were:

Dry matter – 87 to 93%
Crude protein – 23 to 29%
Crude fat – 3 to 12%
Ash – 3 to 6%
Lysine – 0.59 to 0.89%

Similarly, Spiehs *et al.* (2002) reported a range of 0.63 to 0.90% lysine for new generation DDGS. It appears that much of the variation in lysine content of DDGS is related to the variation in corn lysine content being delivered to ethanol plants, and this variability is magnified after starch is removed during ethanol production.

In the study by Cromwell *et al.* (1993), lysine concentration tended to be highest in light-colored DDGS and lowest in the darkest-colored DDGS sources. When the four darkest, burnt smelling sources were fed to chicks, growth rate, feed intake,

Table 7. Comparison of composition and cost of grower diets containing 10% DDGS and formulated on either a total lysine and phosphorus basis or digestible lysine and available phosphorus basis compared to a typical corn-soybean meal diet containing 3 lbs of synthetic lysine.

Ingredient	Typical corn/ SBM-lysine diet	10% DDGS formulated on a total lysine basis	10% DDGS formulated on a digestible lysine basis
Corn, lbs	1463	1301	1286
SBM 44%, lbs	482	446	463
DDGS, lbs	0	200	200
Dicalcium phosphate, lbs	24	19	17
Limestone, lbs	14	17	17
Salt, lbs	6	6	6
L-lysine HCl, lbs	3	3	3
Vit/min premix, lbs	8	8	8
TOTAL	2000	2000	2000
Total cost, $	109.80	108.40	109.18
Difference $	-	- 1.40	-0.62

Feed ingredient prices used: corn = $2.00/bu, SBM 44% = $190/ton, DDGS = $85/ton, dicalcium phosphate = $15/cwt, L-lysine HCl = $1/lb.

and feed conversion were reduced 18%, 13%, and 6%, respectively, compared to chicks fed the lightest-colored DDGS. Results from this study suggest that DDGS that is dark in color and/or has a burnt smell should not be used in swine or poultry diets. Recent unpublished data from Noll and co-workers at the University of Minnesota also suggests that the golden color of DDGS is well correlated with true amino acid digestibility values in DDGS for poultry.

Like energy and amino acid levels, phosphorus levels can also vary in DDGS. The average total phosphorus level of new generation DDGS is 0.78%, but can range from as low as 0.62% to as high as 0.87%. Although some of the variability in phosphorus content appears to be due to the phosphorus content of corn used to produce DDGS, the amount of solubles (phosphorus rich) added to the grains fraction before drying also contributes to the variability in P content of DDGS. Availability of phosphorus in DDGS, based upon University of Minnesota research is 90%, while the NRC (1998) lists the percentage of phosphorus availability at 77%. Because of the economic significance of phosphorus in swine diets, and its impact on manure management plans, diets should be formulated on an available phosphorus basis to take advantage of the available phosphorus provided by DDGS to reduce the need for supplemental dietary phosphorus and reduce phosphorus excretion in manure.

Using DDGS and phytase can eliminate the need for supplemental phosphorus in swine diets

With the eventual adoption of a phosphorus standard for livestock manure management plans, and the reduced need for supplemental inorganic phosphorus in DDGS supplemented swine diets, DDGS can reduce phosphorus excretion in manure as well as reduce diet cost due to less need for supplemental phosphorus in the diet. As shown in Table 8, adding 225 FTU of phytase/lb of complete feed and 376 lbs of DDGS (18.8%) to a swine grower diet (containing 0.85% total lysine), no supplemental dicalcium phosphate is needed when the diet is formulated on an available phosphorus basis. However, diet cost would be slightly increased by an additional $0.11/ton compared to feeding a typical corn-soybean meal diet containing 3 lbs of synthetic lysine and no phytase. Using new generation DDGS and phytase is an economical and practical way to significantly reduce the phosphorus level in swine manure.

Are there concerns about mycotoxins when feeding DDGS?

The incidence of documented cases of mycotoxicosis from feeding DDGS to swine is extremely

Table 8. **Comparison of composition and cost of grower diets containing DDGS and phytase, formulated on an available phosphorus basis, compared to a typical corn/soybean meal diet containing 3 lbs of synthetic lysine.**

	Corn/SBM + 3 lbs lysine	DDGS + phytase
Corn, lbs	1596.6	1272.6
SBM 44%, lbs	353.7	318.8
DDGS, lbs	0	376
Dicalcium phosphate, lbs	23.2	0.0
Limestone, lbs	14.5	19.6
Salt, lbs	6.0	6.0
L-lysine HCl, lbs	3.0	3.0
VTM premix, lbs	3.0	3.0
Phytase	0.0	1.0
TOTAL	2000	2000
Total cost, $	96.25	96.36
Difference $	-	+0.11

Feed ingredient prices used: corn = $2.00/bu, SBM 44% = $190/ton, DDGS = $85/ton, dicalcium phosphate = $15/cwt, L-lysine HCl = $1/lb, phytase = $1.38/lb.

low. However, corn is susceptible to molds that can produce mycotoxins prior to harvest, as well as during storage. The primary mycotoxins of concern to swine are zearalenone, vomitoxin (deoxynivalenol), T-2 toxin, fumonisin, and aflatoxins. In the midwestern US, zearalenone and vomitoxin are the greatest risks.

If corn containing mycotoxins is delivered to an ethanol plant for ethanol production, these mycotoxins are not destroyed or inactivated during the fermentation process and will be present in DDGS produced from this corn source. In fact, the concentration of mycotoxins in DDGS will be 2 to 3 times higher than the initial concentration in the grain because the removal of starch during the fermentation process concentrates all of the unfermentable portions of the grain that remain after fermentation.

Ethanol plants are encouraged to monitor incoming corn for mycotoxins and reject loads that are contaminated to prevent mycotoxins in DDGS. Buyers of DDGS are encouraged to work with their suppliers to establish a quality control protocol for the production of DDGS that should include screening tests and procedures for mycotoxins. However, a typical inclusion rate of 10% dietary DDGS is low enough that if DDGS contained mycotoxins, the levels would be greatly reduced in the final complete feed.

WHICH MYCOTOXIN ASSAY PROCEDURE SHOULD BE USED FOR DDGS?

We have been unable to find published scientific studies that compare the validity of ELISA, TLC, or HPLC methodology for testing mycotoxins in DDGS. Many commercial laboratories use ELISA test kits for determining mycotoxin levels in grain samples. However, we know from experience that using ELISA for determining mycotoxin levels in DDGS results in false positives, due to the interference with salts and oxidizers contained in DDGS with the enzymes in the test. Thin Layer Chromatography is a definitive test for mycotoxins in DDGS and costs about $50 - $60/sample for testing each mycotoxin of concern.

Can DDGS and DDGS diets be pelleted?

Due to the lack of starch, and the relatively high fiber and fat level in DDGS, it is difficult to pellet. Attempting to pellet diets containing high levels of supplemental fat (>5%) and DDGS will reduce throughput in pellet mills.

Do antioxidants need to be added to prevent fat rancidity during DDGS storage?

We monitored fat stability (rancidity) of DDGS for 18 weeks during a layer feeding trial in Jalisco, Mexico and found no problems with rancidity without the use of antioxidants during this time period. The DDGS was stored in a typical upright storage bin at a commercial feed mill. The moisture content of DDGS was 10.9% and the daily high and low temperatures were 26.7 and 10.7°C, respectively.

Are there any concerns about antibiotic residues in DDGS?

Yeast (*Sacchromyces cerevisiae*) is the most important component in ethanol production. Optimizing the health of yeast is essential for maximizing the yield of ethanol from corn starch in dry mill ethanol plants. One of the biggest challenges of maintaining an optimum fermentation environment involves controlling bacterial infections during fermentation. Lactobacillus species are the most common bacterial contaminants of ethanol fermentation. Lactobacilli produce lactic acid and other organic by-products that inhibit yeast activity and consume essential macro- and micronutrients necessary to maintain yeast health. Lactobacilli levels ranging from 10 to 100 million bacteria per milliliter of substrate cause unsuitable conditions for yeast growth and enzyme action during fermentation. When bacterial contamination occurs, fermentations do not reach an end point and alcohol yield is reduced. Yeast and bacteria compete with each other for the glucose present in the mash. By adding approved antimicrobials, designed specifically for ethanol production, to fermentation tanks, competition between yeast and bacteria for glucose in the mash is dramatically reduced or eliminated in favor of yeast growth which can increase ethanol yield by as much as 25%.

Two antimicrobial products are typically used by ethanol plants: virginiamycin and penicillin. Virginiamycin is typically added to yeast propagation tanks, feedstock cookers, and fermentation vats prior to or during fermentation at a level of 0.25 to 2.0 ppm, whereas penicillin is added at a rate of 1 gram per 1,000 liters. The forms of virginiamycin and penicillin used in the ethanol industry are unique compared to forms used in animal feeds. When virginiamycin is added to fermentation tanks it does not affect yeast productivity and does not remain in ethanol after distillation. Furthermore, virginiamycin is destroyed at temperatures greater than 93°C. Since ethanol plants operate dryers at temperatures ranging from 93 to 232°C, virginia-mycin is easily destroyed in DDGS and there are no detectable virginiamycin residues. This makes DDGS a very safe feed ingredient for all livestock feeds.

The commercial form of penicillin commonly used in ethanol production is most stable at a pH between 6 and 6.4, and has a half-life of 14 days when in solution at 24 °C. This form of penicillin is easily inactivated by primary alcohols and some sugars, including sucrose. At a pH of 4.5 or 9.0, the rate of inactivation increases 10-fold, and at a pH of 3.2 or 10.5, inactivation increases 100-fold compared to the rate of inactivation in the most stable pH range of 6 and 6.4. This penicillin-based bacterial inhibitor is completely degraded at pH 3 and a temperature of 37°C for 30 minutes. Therefore, there is no concern of the presence of penicillin residues in DDGS.

What physical characteristics are important for assessing DDGS quality?

COLOR

Color appears to be the most important indicator of quality and nutrient digestibility of DDGS. A golden colored DDGS generally indicates higher amino acid digestibility compared to a dark colored DDGS. Results from a study by Cromwell *et al.* (1993) suggest that corn DDGS that is dark in color and/or has a burned smell has a lower nutritional value in swine or poultry diets. However, color is probably not a good indicator of quality and nutrient digestibility in DDGS produced from sorghum due to differences in color (yellow to bronze) in sorghum grain.

SMELL

Golden colored, new generation DDGS has a sweet, fermented smell unlike lower quality, dark colored DDGS that often has a burned or smoky smell. These differences in color and smell are largely due to types of dryers and drying temperatures used in various ethanol plants, but can also be influenced by the proportion of liquid solubles added to distiller's grains to produce DDGS.

PARTICLE SIZE

We have completed an evaluation of physical characteristics and chemical composition of DDGS among 16 ethanol plants in Minnesota, South Dakota, and Missouri. The average particle size among the 16 ethanol plants was 1282 microns (SD = 305, CV= 24%), and ranged from 612 microns to 2125 microns. Fourteen of the sixteen plants produced DDGS with similar average particle size. DDGS produced by the plant with high average particle size may require further grinding to improve particle size uniformity and optimize nutrient digestibility of DDGS in a complete mixed feed. Ethanol plants that produce DDGS with high amounts of syrup balls tended to have a higher mean particle size. Conversely, DDGS with low average particle size (600 microns) does not flow through bins and feeders and causes increased handling problems.

BULK DENSITY

Bulk density averaged 35.7 lbs/cubic foot (SD = 2.79, CV = 7.8%), but ranged from 30.8 to 39.3 lbs/cubic foot. Bulk density is important for calculating storage capacity and transportation costs when purchasing DDGS.

Does new generation DDGS provide any gut health benefits for pigs?

Several pork producers have observed improvements in gut health in herds with recurring problems with ileitis (porcine proliferative enteropathy) when they added DDGS to finishing diets. *Lawsonia intracellularis*, a microaerophil bacteria that infects immature epithelial cells located in the crypts of the small intestine, causes ileitis. The organism inhibits intestinal cell maturation, which causes cells to multiply without being sloughed off. As a result, the intestinal wall thickens, and in acute cases, hemorrhaging occurs.

We conducted three disease challenge studies where healthy pigs were infected with *Lawsonia intracellularis* to study the effects of various dietary treatments, including adding 10 or 20% DDGS to the diet, on the incidence and severity of intestinal lesions. Conducting disease challenge studies to measure dietary effects on gastrointestinal health is difficult due to the challenge of administering an inoculation dose comparable to field conditions. However, it appears that there may be some benefits of adding DDGS to diets to improve gut health of pigs when confronted with a *Lawsonia* infection, but our results have been inconsistent.

In our first study, we greatly exceeded the inoculation dose of *Lawsonia* and observed no benefit of feeding diets containing 10 or 20% DDGS on reducing the incidence or severity of intestinal lesions caused by ileitis. In our second study, pigs were infected with an inoculation dose close to our goal of 1×10^8 and caused the majority of the pigs to become infected. In this study, adding 10% DDGS reduced the overall prevalence and severity of gastrointestinal tract lesions similar to the response from adding a recommended BMD and chlortetracycline therapeutic regimen. However, there were no additive effects when both antimicrobials and DDGS were combined in the diet. In the third experiment, we used the same infection dose in the second experiment—a dose considered by most veterinarians to be much higher than the infection dosage found in commercial swine operations—and the same source of pigs. But, both lesion incidence and severity were much more severe than in the second experiment. DDGS tended to provide some benefit toward reducing the incidence and severity of intestinal lesions in this experiment. But, adding 5% soy hulls to the diet tended to provide a greater benefit. This beneficial effect of DDGS may be due to its high insoluble fiber content (42%) and/or the presence of compounds with nutraceutical properties. Furthermore, providing DDGS or other sources of insoluble fiber in the diet may provide gut health benefits during a modern ileitis challenge, but does not consistently alleviate the incidence and severity of lesions during severe infections.

Do you want more information on feeding new generation DDGS to livestock and poultry?

For more information on feeding DDGS to swine or other livestock, visit the University of Minnesota DDGS web site at www.ddgs.umn.edu.

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