Chapter 21

Use of DDGS in Swine Diets

Introduction

Corn dried distillers grains with solubles (DDGS) has become the most popular, economical, and widely available alternative feed ingredient for use in U.S. swine diets in all phases of production. Corn DDGS is used primarily as an energy source in swine diets because it contains approximately the same amount of digestible energy (DE) and metabolizable energy (ME) as corn, although the ME content may be slightly reduced when feeding reduced-oil DDGS (see **Chapter 22**). Therefore, it primarily partially replaces high energy ingredients, such as corn in swine diets, but can also partially replace some high protein ingredients, such as soybean meal, and inorganic phosphorus. A scientific review has been published by Stein and Shurson (2009) summarizing all of the published scientific information available on feeding DDGS to swine in the literature up to 2009. A link to the entire review is available in **Chapter 35** of this handbook. The purpose of this chapter is to briefly describe the highlights of this comprehensive literature review, and provide an update of research results published from various studies since 2009.

Nutritional Value of DDGS for Swine

The nutrient composition and digestibility/availability values for DDGS use in swine diet formulation are described in detail in **Chapter 4**. "**Nutrient Composition and Digestibility of DDGS: Variability and *In Vitro* Measurement**". The high energy (3,674 to 4,336 kcal ME/kg DM), moderate protein (27 to 33%, DM basis) and lysine (0.60 to 1.1%, DM) content, along with its relatively high concentration of phosphorus (0.57 to 0.85%, DM basis) and digestibility (50 to 68%) are the key nutritional components that make it an attractive alternative feed ingredient in swine diets. However, like any feed ingredient, DDGS has some limitations that need to be managed to achieve the greatest economic and performance benefits when added to grower-finisher swine diets. Along with its benefits of being a high energy and digestible phosphorus ingredient, it also appears to provide gut health benefits when fed to growing pigs. Limitations for using DDGS at high (>20%) dietary inclusion rates include reduced pork fat firmness, increased manure volume, nitrogen, and phosphorus excretion, and the need for supplemental crystalline amino acids in the diet. However, these limitations are easily overcome by understanding and using proper diet formulation approaches.

Use of DDGS in Starter Diets

Ten experiments were conducted and summarized by Stein and Shurson (2009) that evaluated feeding diets containing up to 30% DDGS to weanling pigs (**Table 1**). In all experiments conducted, there was no change in ADG compared to control diets containing no DDGS, 80% of the experiments resulted in no change in ADFI, and results from 50% of the experiments showed an improvement in gain efficiency, with no effect on pig mortality. These results suggest that DDGS can be used effectively in weanling pig diets at levels up to 30%, 14 to 21 days post-weaning (weaning age at 21 days of age), with no adverse effects on growth performance or mortality.

Table 1. Summary of responses from including up to 30% corn or sorghum DDGS in diets for weanling pigs.[1]

Item	N	Response to dietary corn DDGS		
		Increased	Reduced	Not changed
ADG	10	0	0	10
ADFI	10	0	2	8
G:F	10	5	0	5
Mortality	2	0	0	2

[1]Data calculated from experiments by Whitney and Shurson (2004), Gaines et al. (2006), Linneen et al. (2006), Spencer et al. (2007), Barbosa et al. (2008), and Burkey et al. (2008).
Source: Stein and Shurson (2009).

Two more recent studies confirmed these conclusions. Zhu et al. (2010) conducted 4 experiments to evaluate the effects of including 30% DDGS in late nursery diets on pig growth performance and compare the effects of pelleted and meal diets containing 30% DDGS on growth performance and nutrient digestibility. Their results showed that 30% DDGS can be used in late nursery diets for 10 to 23 kg pigs without affecting growth performance. Pelleting DDGS diets improves pig growth performance and feed efficiency by increasing digestibility of energy and most nutrients. Similarly, Tran et al. (2011) demonstrated that DDGS can be included in diets for nursery pigs at the level of 15% during the entire nursery period, or up to 30% during the late nursery period without compromising growth performance. It appeared that incorporation of lactose in the diet may help maintain growth performance in weanling pigs fed diets containing DDGS, and feeding lactose in combination with DDGS may affect fecal *Lactobacillus* spp. in nursery pigs.

Use of DDGS in Grower-Finisher Diets

Growth performance results from 25 experiments in which corn DDGS was added at levels up to 30% of the diets growing-finishing are summarized in **Table 2** (Stein and Shurson, 2009). The majority of these studies showed no change in ADG (72% of experiments), ADFI (65% of experiments), and G:F ratio (64% of experiments), with the others showing either increases or decreases in performance. Based on the information provided from reports of these 25 experiments, it is difficult to explain why pig performance was maintained in most, but not in all experiments in which DDGS was included in the diets. It is possible that when performance was reduced, the DDGS used in the experiments may have been of a poorer quality (lower nutrient digestibility) than expected. Another possible explanation is that the reduction in performance in some of the experiments may have been due to excess nitrogen from crude protein at high dietary inclusion rates. In most of the experiments where ADG was reduced, a reduction in ADFI was also observed. This reduction in ADFI may have been due to using lower quality DDGS sources because results from other studies have shown that if pigs are given a choice of diets, they prefer to consume diets containing no DDGS (Hastad et al., 2005; Seabolt et al., 2010). Other researchers have speculated that reduced feed intake observed in some experiments may be due to excessively high sulfur content of the DDGS source used. However, Kim et al. (2011) conducted 4 experiments and showed that dietary S concentration does not negatively affect feed preference, feed intake, or growth performance of weanling or growing-finishing pigs fed diets based on corn, soybean meal, and DDGS. Furthermore, Hilbrands et al. (2012) showed that periodic inclusion and removal of 40% DDGS from diets did not adversely affect growth performance or have important effects on carcass quality regardless of the SID AA digestibility of the DDGS used. These results indicate that it is possible to abruptly incorporate and remove DDGS from grower-finisher swine diets without meaningful detrimental effects on growth performance or carcass quality.

Table 2. Effects of including corn DDGS in diets fed to growing-finishing pigs on growth performance and carcass characteristics.[1, 2]

Item	N	Response to dietary corn DDGS		
		Increased	Reduced	Not changed
ADG	25	1	6	18
ADFI	23	2	6	15
G:F	25	4	5	16
Dressing percentage	18	0	8	10
Backfat, mm	15	0	1	14
% carcass lean	14	0	1	13
Loin depth, cm	14	0	2	12
Belly thickness, cm	4	0	2	2
Belly firmness	3	0	3	0
Iodine value	8	7	0	1

[1] Data based on experiments published after 2000 and where a maximum of 30% DDGS was included in the diets.
[2]Data summarized from experiments by Gralapp et al. (2002), Fu et al. (2004), Cook et al. (2005), DeDecker et al. (2005), Whitney et al. (2006a,b,), McEwen (2006, 2008), Gaines et al. (2007a,b); Gowans et al.(2007), Hinson et al. (2007), Jenkin et al. (2007), White et al. (2007), Widyaratne and Zijlstra (2007), Xu et al. (2007; 2010,a,b), Augspurger et al. (2008), Drescher et al. (2008), Duttlinger et al. (2008), Hill et al. (2008a), Linneen et al. (2008), Stender and Honeyman (2008), Weimer et al. (2008), and Widmer et al. (2008).

In the Stein and Shurson (2009) summary, 10 of the 18 experiments measuring carcass dressing percentage in pigs fed DDGS diets, showed no differences compared with carcasses from pigs fed corn-soybean meal diets with no DDGS (Fu et al., 2004; McEwen, 2006; 2008; Xu et al., 2007; Augspurger et al., 2008; Drescher et al., 2008; Duttlinger et al., 2008; Hill et al., 2008a; Stender and Honeyman, 2008; Widmer et al., 2008). However, feeding diets containing DDGS resulted in reduced carcass dressing percentage in 8 experiments (Cook et al., 2005; Whitney et al., 2006a; Gaines et al., 2007a and b; Hinson et al., 2007; Xu et al., 2010a; Linneen et al., 2008; Weimer et al., 2008). Previous studies have shown that adding ingredients high in fiber to growing-finishing pig diets may reduce the dressing percentage because of increased gut fill and increased intestinal mass (Kass et al., 1980). This may explain the reduced dressing percentage observed in pigs fed DDGS diets in some experiments, but it is unknown why this effect was not observed in other experiments. Recently, Agyekum et al. (2012) showed that pigs fed a diet containing 30% DDGS have reduced dressing percentage and increased visceral organ mass compared with pigs fed a corn-soybean meal diet, but the addition of a multi-enzyme complex to the DDGS diet did not affect dressing percentage and visceral organ mass compared with pigs fed a corn-soybean meal diet.

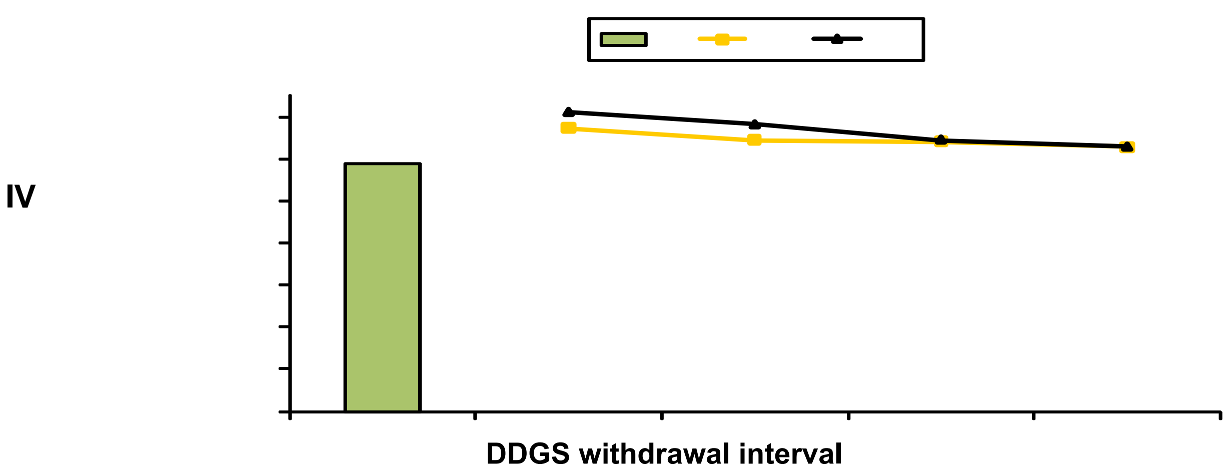
Backfat thickness, loin depth, and % carcass lean are generally unaffected by adding up to 30% DDGS to the diet (**Table 2**). Two studies reported a reduction in backfat thickness (Weimer et al, 2008; Xu et al., 2010a), and two studies reported a reduction in loin depth (Whitney et al., 2006a; Gaines et al., 2007b) when DDGS diets were fed. The reduction in loin depth observed in those two studies was likely due to lower ADG and lighter market weights of pigs fed the DDGS diets. Only one study (Gaines et al., 2007b) reported a reduction % carcass lean.

Adding DDGS to grower-finisher swine diets can negatively affect belly and pork fat quality, especially at high (> 20%) dietary inclusion rates. Dried distillers grains with solubles contains approximately 10% corn oil, which is comprised of nearly 60% linoleic acid (long-chain, unsaturated fatty acid). Feeding diets containing high amounts of unsaturated fatty acids, particularly linoleic acid, can reduce fat firmness and increase the amount of unsaturated fatty acids in pork fat. Results from some studies where DDGS was fed to grower-finisher pigs showed that belly thickness was linearly reduced when increasing levels of corn DDGS were added to the diet (Whitney et al., 2006a; Weimer et al., 2008). However, pigs fed DDGS containing diets in these two studies also had reduced ADG, and as a result, were marketed at a lighter weight than the control pigs, which may have resulted in reduced belly thickness. In studies where no differences in belly thickness was observed (Widmer et al., 2008 and Xu et al., 2010b), no differences in the final body weight of the pigs were also observed. All of the studies (3) reporting belly firmness measurements (Whitney et al., 2006a; Xu et al., 2010a; Widmer et al., 2008), showed that belly firmness was reduced in pigs fed diets containing DDGS compared with pigs fed diets containing no DDGS. This observation is supported by the results from 8 studies showing that the iodine value (ratio of unsaturated to saturated fatty acids) of the belly fat is increased in pigs fed DDGS (Whitney et al., 2006a; White et al., 2007; Xu et al., 2010a; 2008a; Hill et al., 2008a; Linneen et al., 2008; Stender and Honeyman, 2008). Cromwell et al. (2011) fed diets containing 30 or 45% DDGS and reported no major effects on growth performance, but resulted in bellies from these pigs became softer. Regression analysis indicated that iodine values increased 4.3 units for every 10 percentage unit inclusion of DDGS in the diet.

Carcass fat iodine value can be a reasonable indicator of carcass fat quality because high iodine values result in softer bellies. Since pork fat firmness is consistently reduced when feeding growing-finishing pigs increasing amounts of DDGS, researchers have been evaluating alternative nutritional strategies to reduce the negative effects of DDGS on iodine values. White et al. (2007) showed that the addition of 1% conjugated linoleic acids to diets containing 20 or 40% corn DDGS for 10 d prior to pig harvest, reduced pork fat iodine values and the n6:n3 ratio. Pompeu et al. (2009) confirmed the positive effects of adding conjugated linoleic acid to finishing pig diets containing 30% DDGS on improving the fatty acid profile and pork fat quality. Thus, addition of conjugated linoleic acid to DDGS containing diets during the late finishing phase is effective for reducing iodine values in carcass fat, but this additive is not commercially approved for use in many countries. A more practical approach for meeting desired pork fat quality standards is to remove DDGS from the diet during the final 3 to 4 weeks prior to harvest (Hill et al., 2008a; Xu et al., 2010b; **Figure 1**).

Other researchers have evaluated pork fat quality when adding supplemental animal fat sources to high inclusion rate DDGS diets. Stevens et al. (2009) showed that feeding a corn-soybean meal diet, with or without 5% choice white grease, during a 26 day dietary DDGS withdrawal program partially recovered some of the adverse effects caused by linoleic acid from the DDGS diet. However, they indicated that a longer DDGS withdrawal period is required for complete recovery of pork fat quality. The addition of a dry animal fat source (4% of the diet) high in saturated fatty acids (70%) did not alleviate the increase in iodine value resulting from the addition of 30% DDGS to the diet (Freitas et al., 2009), which was most likely due to the low digestibility of the fat source used in the study. Benz et al. (2010) fed diets containing various levels of DDGS (0 to 20%) and 6% choice white grease and showed that gilts had greater C18:2n-6, PUFA, and PUFA:SFA ratio and lower C14:0 concentrations in backfat and belly fat, but not jowl fat compared to barrows. Gilts also had greater belly fat IV than barrows, but there were no differences in backfat and jowl fat IV between gilts and barrows. Feeding increasing amounts of DDGS linearly increased the IV of backfat, jowl fat, and belly fat, jowl fat was less responsive to increased dietary levels of DDGS than backfat and belly fat. Pigs fed diets with 20% DDGS and 6% choice white grease exceeded the maximum jowl IV of 73 g/100 g established as a standard by some U.S. pork processing facilities. Pomerenke et al. (2011) also showed that adding 5% beef tallow (saturated animal fat source) was not effective in improving pork fat firmness when feeding 30% DDGS diets. See **Chapter 23** for a more detailed discussion on impacts of feeding DDGS on pork fat quality and feeding solutions to manage this challenge.

Figure 1. Effects of Dietary DDGS Level (0, 15, and 30%) and Withdrawal Interval (0, 3, 6, and 9 Weeks Pre-harvest) on Iodine Value (IV) of Belly Fat.[1]



Note: D15-9 wk and D30-9 wk = control, others > control
[1] Xu et al. (2010b)

Use of DDGS in Gestation and Lactation Diets

Several studies have shown that feeding sows diets containing up to 50% DDGS in gestation and up to 30% DDGS in lactation had no negative effects on reproductive performance and milk composition (Wilson et al., 2003; Hill et al., 2008b; Song et al., 2010; Greiner et al., 2008). Wilson et al. (2003) observed an increase in litter size from sows fed a 50% DDGS during gestation and 30% DDGS during lactation in the preceding reproductive cycle. However, this response has not been confirmed in subsequent studies.

DDGS and Manure Management

Limited data are available on the effects of feeding DDGS diets to swine on gas and odor emissions and manure composition. Spiehs et al. (2000) was the first to report that there were no effects from manure obtained from growing-finishing pig fed diets containing 20% DDGS over a 10-week period on hydrogen sulfide (H_2S), ammonia (NH_3), or odor detection levels compared to manure from pigs fed corn-soybean meal diets. In this study, feeding DDGS containing diets tended to increase N excretion, but P retention was not different between dietary treatments. Gralapp et al. (2002) fed diets containing 0, 10, or 20% DDGS to finishing pigs and found no differences in total solids, volatile solids, chemical oxygen demand, or total N or P concentration of manure among dietary DDGS levels. However, odor concentration tended to increase with increasing dietary levels of DDGS. McDonnell et al. (2011) confirmed that increasing the level of DDGS in the growing-finish pig diets increases total nitrogen excretion in manure, but did not observe an increase in ammonia emissions. In contrast to the findings by Spiehs et al. (2000). Li et al. (2011a) demonstrated that feeding diets containing 20% DDGS to growing pigs increase hydrogen sulfide, methane, ammonia, and nonmethane total hydrocarbon emissions from pigs, but organic sources of trace minerals are a promising mitigation strategy to alleviate the adverse effect of DDGS on hydrogen sulfide emissions.

In studies involving sow manure composition, Hill et al. (2008b) showed that adding DDGS to lactating sow diets reduced the concentration of P in the feces compared to feeding a corn-soybean meal diet without DDGS, but it is unknown if total P excretion was reduced because DM digestibility of the diets was not determined. Li et al. (2011b) showed that feeding diets containing 40% DDGS to gestating sows decreased apparent dry matter digestibility of the diet and increased the fecal output, but did not affect the total volume of slurry produced or N, P, or K output in slurry.

Four experiments were conducted to evaluate effects of diet formulation method, dietary level of DDGS, and use of microbial phytase on nutrient balance in nursery and grower-finisher pigs (Xu et al., 2006a;b;c;d). Results of these studies showed that adding DDGS to nursery pig diets generally results in a reduction in dry matter digestibility, an increased fecal excretion, and phytase is more effective than DDGS in reducing total manure phosphorus excretion. Furthermore, diets formulated to contain Ca:available P ratios (2:1 to 3:1) established by NRC (1998) are acceptable when 20% DDGS and phytase are added to nursery diets to minimize P excretion in the manure. Unlike for nursery aged pigs, feeding diets containing DDGS without or with phytase to growing-finishing pigs resulted in no change in DM digestibility and manure excretion.

Almeida and Stein (2010) conducted 3 experiments to test the hypotheses that pigs fed diets that are equal in digestible P would perform equally regardless of the concentration of total P in the diets, and that the addition of microbial phytase, DDGS, or a combination of phytase and DDGS would result in a reduction in P excretion. Results from this study showed that the addition of phytase increased the standardized total tract digestibility (STTD) of P in corn and SBM, but had no effect on the STTD of P in DDGS. Most importantly, diets can be formulated based on STTD values without compromising pig performance, and dietary phytase, DDGS, or the combination of phytase and DDGS will reduce P excretion by growing pigs. In a follow-up study, Almeida and Stein (2012) conducted an experiment where they supplemented corn and corn co-products swine diets with 500, 1,000, or 1,500 FTU of microbial phytase/kg. Their results showed a linear increase in STTD of P in corn (from 40.9 to 67.5, 64.5, and 74.9%, respectively), DDGS (from 76.9 to 82.9, 82.5, and 83.0%, respectively), HP-DDG (from 77.1 to 88.0, 84.1, and 86.9%, respectively), and corn germ (from 40.7 to 59.0, 64.4, and 63.2%, respectively). They concluded that microbial phytase has a much greater effect on STTD of P in corn and corn germ than in DDGS and HP-DDG. Therefore, adding DDGS to swine diets reduces manure phosphorus content when diets are formulated in a digestible or available P basis.

Effect of Feeding DDGS on Gut Health of Growing Pigs

Whitney et al. (2006 b,c) conducted two experiments to determine if including DDGS in the diet of young growing pigs reduces the incidence or severity of clinical signs, fecal shedding, intestinal lesions, and/or cellular infection indicating porcine proliferative enteropathy (ileitis) after challenge with *Lawsonia intracellularis*. In the first experiment, adding DDGS to the diet did not positively affect lesion prevalence and length, proliferation of *L. intracellularis*, or severity of lesions. In the second experiment, the *L. intracellularis* dosage rate for challenging pigs was reduced by 50% compared to the first experiment, and feeding a diet containing 10% DDGS reduced ileum and colon lesion length and prevalence, and reduced the severity of lesions in the ileum and colon compared to other challenged pigs. Pigs fed the antimicrobial regimen reduced prevalence and severity of lesions in the jejunum, and tended to have reduced total tract lesion length. When the combination of DDGS and antimicrobial (BMD and chlortetracycline) were fed, no additional advantages were observed in reducing the length, severity, or prevalence of lesions. These results indicate that dietary inclusion of DDGS may aid the young growing pig in resisting a moderate ileitis challenge similar to a U.S. approved antimicrobial regimen, but under more severe challenges, DDGS may not be effective.

Recommended Maximum Inclusion Rates of DDGS in Swine Diets

Based upon numerous research studies conducted in each phase of swine production, the maximum usage rate of DDGS in swine diets is as follows:

Production Phase	Maximum % of Diet
Nursery pigs (>7 kg)	30
Grow-finish pigs	45[1]

Developing gilts	30
Gestating sows	50
Lactating sows	30
Boars	50

[1]Lower inclusion rates may be warranted in certain pork markets where specific pork fat quality standards must be met.

These recommendations assume the use of high quality, highly digestible DDGS sources that are free from mycotoxins. Nursery diets containing up to 30% DDGS will support growth performance equivalent to feeding pigs fed corn-soybean meal based diets provided diets are formulated on a digestible amino acid and available phosphorus basis. Similarly, grower-finisher diets containing levels up to 45% 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, some markets may require feeding no more than 20% DDGS in grower-finisher diets continuously, or withdrawing it from the diet 3 to 4 weeks before harvest to achieve desired pork fat quality. Likewise, developing gilt diets can contain up to 30% DDGS. For sows, up to 50% DDGS can be successfully added to gestation diets, and 30% DDGS can be added to the lactation diet if DDGS is free of mycotoxins.

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