Sorghum in Swine Production Feeding Guide

SORGHUM CHECKOFF SM

Sorghum & Livestock

A Win-Win Situation

"We at Texas Farm have used sorghum in our swine diets since the company's inception. We have worked closely with sorghum producers in the area to provide an outlet for their grain. This relationship has strengthened with time and has proven to be a win-win situation."

"At Texas Farm, we are witness to the advantages of sorghum used in the swine industry. Today, not only have these advantages been limited to cost procurement, but also to the quality of our end product. Sorghum has afforded Texas Farm the ability to maintain and improve carcass characteristics and keep from creating issues in the growth or development of our swine herd. We look forward to using more sorghum in the future and working closely with sorghum producers to meet our needs."

- Sam Nakada, *Texas Farm LLC General Manager*

Texas Farm LLC is a swine farrow-to-finish operation located in the Texas Panhandle

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Cover photo courtesy of Texas Pork Producers Association.

Written by:

Dr. Mike Tokach

Dr. Bob Goodband

Dr. Joel DeRouchey

Kansas State University

Manhattan, Kan.

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Feeding Value of Sorghum and Sorghum Dried Distillers Grains with Solubles for Swine

Introduction

Grain sorghum is a feedstuff with an excellent nutritional value for swine. Numerous feeding trials with nursery and finishing pigs and gestating and lactating sows in the last 20 years have demonstrated the feeding value of sorghum relative to corn and other grains. The research has demonstrated that sorghum grain contains 96 percent the energy content of corn. However, recent data shows when processed correctly and balanced for digestible amino acid and available phosphorus concentrations, grain sorghum has a feeding value greater than the 96 percent value of corn. Grain sorghum can totally replace corn, wheat or barley as the cereal grain source for all classes of swine diets. While sorghum has a slightly lower fat and energy value than corn, from a carcass fat quality prospective, this is a positive quality as pigs that are fed sorghum deposit a firmer carcass fat. This provides an advantage relative to corn for bacon processors and in many fresh pork markets. However, sorghum DDGS are higher in protien, making them an excellent alternative protien source.

Only recently has research been conducted with sorghum DDGS. However, data indicates that similar growth rate can be achieved with diets containing sorghum DDGS as diets containing corn DDGS or corn-soybean meal diets without DDGS. Similar to the comparison between their parent grains, sorghum DDGS has a slightly lower energy level than corn DDGS due to the lower fat content.

Grain sorghum and sorghum DDGS provide an excellent opportunity for swine producers or feed suppliers to lower feed costs. As our understanding of feed processing and nutrient profile of grain sorghum has increased, greater opportunities for expanded usage of grain sorghum exist to exploit its full potential in swine diets.

“Grain sorghum and sorghum DDGS provide an excellent opportunity for swine producers or feed suppliers to lower feed costs.”

Feeding Value of Grain Sorghum

Composition of Grain Sorghum

Grain sorghum can totally replace all the corn, wheat or barley in all swine diets. An important consideration when using grain sorghum-based diets is its slightly lower energy and lysine content relative to corn (Table 1). However, sorghum contains greater amounts of available phosphorus than corn. While grain sorghum is frequently substituted on an equal weight basis with corn, slight adjustment of the soybean meal or synthetic amino acids and supplemental phosphorus can be made to take full advantage of grain sorghum’s nutrient composition. Therefore, when using grain sorghum, it is very important to use its standardized ileal digestible (SID) amino acid content and available phosphorus values in diet formulation.

"...fine grinding of grain sorghum can increase its digestible energy content by 3 percent..."

Table 1. Typical nutrient composition (as-fed)[1]

	Sorghum	Corn
Dry matter, %	89.0	89.0
Energy, kcal/lb.		
Digestible	1,533	1,598
Metabolizable	1.515	1,551
NE INRA[2]	1,188	1,086
NE NRC	1,023	1,086
Crude protein, %	9.2	8.3
Calcium, %	0.03	0.03
Phosphorus, %	0.29	0.28
Available P, %	0.058	0.039
Crude fat, %	2.9	3.9
Linoleic acid, %	1.13	1.92
Crude fiber, %	2.4	2.15
NDF, %	18.0	9.6
ADF, %	8.3	2.8
Total amino acids, %		
Lysine	0.22	0.26
Isoleucine	0.37	0.28
Leucine	1.21	0.99
Methionine	0.17	0.17
Cysteine	0.17	0.19
Threonine	0.31	0.29
Tryptophan	0.10	0.06
Valine	0.46	0.39

[1]NRC. 1998. Nutrient Requirements of Swine. 10th rev. ed. Natl. Acad. Press, Washington, D.C.
[2]INRA. 2004. Tables of composition and nutritional value of feed materials. 2nd ed. D. Sauvant, J.M. Perez, and G. Tran. 304 p.

Amino Acid Profile

Sorghum contains more of the limiting amino acid tryptophan than corn. Thus, greater quantities of supplemental amino acids like lysine, methionine and threonine can be used to replace soybean meal in the diet. This advantage allows for potentially less expensive diet formulation options with grain sorghum-based diets compared with corn. The SID of amino acids is slightly lower than the levels for corn (Table 2). Due to the expanded use of synthetic amino acid fortified diets in the swine industry, the economic advantage for grain sorghum in swine diets has increased compared to corn.

Energy Value

The decreased energy content of grain sorghum relative to corn is a result of sor

ghum's lower fat content. As a result, pigs fed sorghum-based diets will generally have 1 to 2 percent poorer feed efficiency than those fed corn. One factor essential in order to maximize sorghum's digestible energy content is proper feed processing. Grain sorghum has a small hard kernel which makes proper processing essential to obtain optimum particle size. Research shows fine grinding of grain sorghum can increase its digestible energy content by 3 percent compared with coarse grinding[1]. Grinding grain sorghum from a particle size of 900 microns to 500 microns improves feed efficiency by 6 percent. There appears to be no differences in nutritional value to the pig for grain sorghum varieties of various colors or hardness.

Table 2. Standardized ileal digestibility (SID, %) coefficients of corn and sorghum

Item	Corn[1]	Difference[1]	Sorghum
Lysine	78	-6.4	72
Isoleucine	87	-10	77
Leucine	92	-10.2	82
Methionine	90	-8.4	82
Cysteine	86	-9.7	76
Threonine	82	-6.4	76
Typtophan	84	-4.1	80
Valine	87	-9.3	78

[1]NRC. 1998. Nutrient Requirements of Swine. 10th rev. ed. Natl. Acad. Press, Washington, D.C.

[2]Difference between standardized ileal digestibility of corn and sorghum [19-21,36]

"…diets formulated with grain sorghum require less supplemental inorganic phosphorus [than corn]."

Available Phosphorus

An important characteristic from an economic and environmental standpoint is that grain sorghum contains greater available phosphorus than corn. Therefore, diets formulated with grain sorghum require less supplemental inorganic phosphorus (monocalcium- or dicalcium-phosphate). As a result there would be less phosphorus excreted in swine waste, a beneficial factor for the environment. This also improves the economic advantage of sorghum grain compared to corn in swine diets.

Fatty Acid Profile

The lower fat content of sorghum compared with corn, along with a more favorable fatty acid profile, provides sorghum with a distinct advantage over corn in improving pork fat quality. Fatty acid profile of the diet fed to pigs influences the carcass fat iodine value of pigs which is a measure of carcass fat. Fat quality is extremely important in today's pork processing industry. Pork products with soft fat, more unsaturated fatty acids, are discriminated against as they can become rancid faster and the bellies are more difficult to slice for bacon as the fat has a higher tendency to "smear" resulting in a less desirable product. The fat contained in sorghum has less unsaturated fatty

fed sorghum-based diets should have firmer fat and lower iodine value than pigs fed corn-based diets.

The advantages of sorghum compared with corn for fat quality has been confirmed in research. Pigs fed sorghum had less linoleic acid and a lower polyunstaturated fatty acid to saturated fatty acid ratio in backfat and jowl fat than pigs fed corn[2] (Table 3). More importantly, the iodine value was lower for pigs fed sorghum than for those fed corn, confirming that pigs fed sorghum-based diets had firmer fat than those fed corn. Another advantage of the low iodine value of grain sorghum is that it allows more flexibility in diet formulation. Nutritionists can add co-product ingredients generally high in iodine value, such as added fat or dried distillers grains with solubles, and still maintain lower iodine values compared to corn-based diets containing the same amounts of these co-products.

"Sorghum has many attributes that enhance its nutritional value for pigs."

In summary, grain sorghum has many attributes that enhance its nutritional value for pigs. Grain sorghum has a favorable digestible amino acid profile, available phosphorus content, and fatty acid profile for pig diets. When processed correctly, the energy concentration is also greater than previously thought.

Table 2. Effects of grain source on pork fat quality[1]

	Grain source			
Item	**Corn**	**Sorghum**	**SE**	**P-value**
Backfat quality				
Palmitic acid (16:0), %	24.2	24.4	0.2	0.26
Stearic acid (18:0), %	12.5	12.5	0.2	0.97
Oleic acid (18:1c9), %	38.7	40.4	0.04	0.01
Linoleic acid (18:2n6), %	14.3	12.2	0.3	0.01
PUFA:SFA ratio	0.42	0.36	0.01	0.01
Iodine value, g/100 g	65.8	63.9	0.5	0.01
Jowl fat quality				
Palmitic acid (16:0), %	22.8	23.1	0.2	0.16
Stearic acid (18:0), %	9.6	9.8	0.1	0.19
Oleic acid (18:1c9), %	41.2	42.6	0.2	0.01
Linoleic acid (18:2n6), %	14.6	12.9	0.3	0.01
PUFA:SFA ratio	1.49	0.43	0.01	0.01
Iodine value, g/100 g	70.3	68.3	0.5	0.01

[1]Adapted from Benz et al. (2010)

Summary of Feeding Trials with Sorghum Relative to Corn

Nursery Pigs

Starch provided from cereals is the major energy-yielding component of the diet of weanling pigs, where it contributes more than double the digestible energy compared with that from dietary fat. Corn is the most commonly used cereal in piglet diets be-

cause of its wide availability, low fiber, and high energy content. However, numerous studies have demonstrated that sorghum can be used successfully to replace corn in nursery diets.

In a summary of nursery studies comparing sorghum to corn-based diets (Table 4), the average relative value of sorghum was 98, 99 and 99 percent of the value of corn for ADG, ADFI, and G:F, respectively [1,3-6]. Overall, feeding sorghum to weanling pigs had no effect on feed efficiency, However, there was greater variation in ADG and ADFI responses to feeding sorghum between studies and compared to studies on growing-finishing pigs. Researchers in one study observed lower ADFI and ADG in weanling pigs fed sorghum in one experiment. However, feeding sorghum improved ADFI and ADG in a subsequent experiment[3]. Other researchers compared both hard and soft sorghum to corn in nursery diets with both sorghum varieties resulting in lower ADFI and ADG compared to pigs fed corn-based diets[1]. In contrast, another research study showed greater ADG and better feed efficiency in feeding sorghum to nursery pigs compared to corn[4]. More recent studies showed no differences in ADG, ADFI, and G:F between nursery pigs fed sorghum and corn-based diets[5-6].

"Sorghum can be used successfully to replace corn in nursery diets."

Table 4. Relative value (%) of sorhgum versue corn in nursery pigs

Study	ADG	ADFI	G:F	Reference
1	90	91	99	Richert et al. (1992) Exp. 1
2	113	112	101	Richert et al. (1992) Exp. 2
3	80	84	95	Healy et al. (1994) Hard
4	84	88	95	Healy et al. (1994) Soft
5	111	104	108	Hongtrakul et al. (1998)
6	103	105	99	Jones et al. (2000) Mill-run
7	105	105	100	Jones et al. (2000) Red
8	103	101	102	Jones et al. (2000) White
9	96	103	93	Fialho et al. (2004)
Average	98	99	99	

Growing-Finishing Pigs

A 1985 summary involving 10 growing-finishing experiments reported that pigs that were fed sorghum had 98 percent of ADG and 97 percent of G:F of pigs fed corn[7]. However, more recent studies reveal greater feeding value for sorghum in finishing pigs than previously ascribed[8-13]. On average, these studies show that sorghum-fed pigs have 103, 106 and 98 percent of the ADG, ADFI, and G:F of finishing pigs that were fed corn (Table 5). The observed improvements in the relative value of sorghum may be due mainly to the introduction and widespread use of improved cultivars of sorghum and a better knowledge of processing sorghum-based diets. Overall, grain sorghum can be used to replace all of corn without affecting growth performance of finishing pigs.

Previously, feeding sorghum to finishing pigs generally did not affect carcass characteristics[9-11]. However, a more recent study observed that sorghum-fed pigs tend to have lower yield, lean percentage and thicker 10th rib backfat compared to those fed corn-based diets[2]. The lower carcass yield and leanness of pigs that were fed sorghum observed in this study may be due to greater energy, or feed intake compared to pigs that were fed corn, which may have resulted to increased carcass fatness.

"Sorghum can be used to replace all of corn without affecting growth performance of finishing pigs."

Table 5. Relative value (%) of sorghum versus corn in finishing pigs

Study	ADG	ADFI	G:F	Reference
1	104	109	96	Brand et al. (1990) variety 1
2	102	108	95	Brand et al. (1990) variety 2
3	98	104	95	Hancock et al. (1992)
4	106	106	100	Johnston et al. (1998)
5	104	109	95	Shelton et al. (2004) waxy sorghum
6	106	114	93	Shelton et al. (2004) non-waxy sorghum
7	104	100	104	Issa (2009)
8	99	100	100	Seaboard Farms (2010)
9	106	105	101	Benz et al. (2010)
Average	103	106	98	
Cromwell (1985 review)	98	102	97	10 exp summary

Sows

Research assessing the value of feeding sorghum to sows is limited. One research study fed either sorghum or corn-based diets to gestating sows and revealed no differences on either sow or litter performance. However, results varied when sorghum was compared to corn in lactation diets (Table 6)[14,15]. In one study, sows that were fed sorghum had lower ADFI than sows that were fed corn, which resulted in a tendency for lower litter weaning weights and decreased litter weight gains[14]. In contrast, a separate research study did not observe significant differences in lactation ADFI and litter performance between sows that were fed sorghum or corn[15]. Feeding sorghum did not affect lactation weight change, weaning-to-estrus interval, or litter size at weaning in either study[14,15]. Though more research is needed to more appropriately determine the value of sorghum in sow diets, feeding sorghum to sows can generally support a level of reproductive performance that is equal to feeding corn.

Table 6. Relative value (%) of sorghum versus corn in lactating sows

	Relative value		
Item	Louis et al. (1991)[14]	Johnston et al. (1998)[15]	Average
Sow performance			
Lactation ADFI	90	102	96
Lactation weight change	90	62	76
Weaning-to-estrus interval	94	111	102
Litter performance			
Litter size born alive	108	102	105
Litter size at weaning	103	99	101
Litter BW at birth	99	101	100
Litter BW at weaning	93	98	96
Litter BW gain	92	97	95

Processing of Sorghum

One of the keys to unlocking sorghum's nutritional value is proper feed processing. As with any feed ingredient fed to swine, feed processing and ultimate particle size is essential to proper nutrient utilization of the ingredient. Grain sorghum is no different. Grain sorghum has a small kernel and is very hard in comparison with corn. Therefore, disrupting the intact kernel and exposing greater surface area is essential for improved digestibility of the pig. Our understanding of proper feed processing of sorghum over the last 15 years may be one of the reasons why its nutritional value has increased relative to corn in the more recent experiments (Tables 4, 5 and 6).

Research has evaluated growth performance of pigs weaned at 21 days of age and fed starter diets in which the grain, corn, and hard or soft endosperm sorghum, was ground to 900, 700, 500 or 300 microns[1]. In this study, reducing particle size had very little impact on average daily gain, but, as particle size was reduced, an improvement (quadratic, $P < 0.01$) was observed in feed efficiency. Pigs that were fed grain ground to 500 microns showed a 6 percent improvement in feed efficiency compared to those pigs that were fed diets containing grain ground to 900 microns. However, the trend for poorer G:F of pigs that were fed the diets containing grain ground to 300 microns is also important to consider. Therefore, these and other data suggest a dietary particle size of approximately 500 to 600 microns, or grinding as finely as possible yet maintaining flow ability of the diet through automatic feeding systems, is required to optimize both pig performance and milling efficiency.

In the past, we have considered either a hammer mill or a roller mill to be sufficient for grinding sorghum. Each type of mill has its own advantages and disadvantages. With hammer mills, the small kernel size of grain sorghum requires a small screen

($^1/_8$th inch) in order to achieve the targeted particle size. A disadvantage of grinding sorghum with a hammer mill is that it will have a greater standard deviation of particles. This means the distribution of particles will be wider than grain ground with a roller mill. A roller mill will tend to slice the grain, producing a more uniform shaped particle and less standard deviation or dustiness. It is recommended that the rolls on a roller mill have 14 to 16 corrugations per inch to aid in this slicing action. Because grain ground with a roller mill is more uniform in shape and distribution, research has shown that it will have greater flow ability than grain ground with a hammer mill. This is especially important as we process grains to finer particle sizes to maximize growth and feed efficiency. Freer flowing grain will also allow nutritionists the potential to add more co-products like added fat to the diet and still maintain diet flow ability.

"Because of its nutrient profile... sorghum affords nutritionists different opportunities for diet formulations."

Feeding Recommendations for Grain Sorghum

Grain sorghum can replace all the corn, wheat or barley in diets fed to all classes of swine. Because of its nutrient profile, including greater amounts of digestible tryptophan and available phosphorus, it affords nutritionists different opportunities for diet formulation. One option would be to simply replace it on an equal weight basis with corn and make allowances for the greater available phosphorus by reducing the amount of monocalcium phosphorus in the diet (Table 7, Option 1). This is the simplest substitution options, but it takes into account the least nutritional value of grain sorghum. The second diet option takes into account both the greater amino acid digestibility and available phosphorus content of grain sorghum relative to corn (Table 7). This diet option contains greater amounts of crystalline amino acids and less soybean meal and monocalcium phosphate. It takes full advantage of grain sorghum's high digestible tryptophan concentration and allows for the greater use of crystalline amino acids and therefore reduces the amount of soybean meal in the diet. Lastly, the third option adds a small amount of fat to the diet to balance the energy content of the diet (Table 7). In this option, the corn and sorghum diets not only contain the same amino acid fortification but also the identical energy content. Therefore, nutritionists have numerous options to take advantage of sorghum's versatility in diet formulation.

In conclusion, recent research with nursery and growing finishing pigs shows improved nutritional and feeding value of grain sorghum than studies conducted in the 1970's and 1980's. The higher feeding value is likely because of better understanding of the digestible amino acids and available phosphorus contained in grain sorghum, as well as improvements in feed processing. A summary of studies with nursery pigs show a feeding value of 98 to 99 percent for sorghum compared with corn. Wherein, the past grain sorghum was valued at 96 percent the value of corn, it now appears that sorghum has a greater feeding value than in the past. In addition, sorghum's flexibility in diet formulation offers nutritionists the ability to lower diet costs yet maintain similar growth performance of pigs.

Table 7. Example diets with grain sorghum replacing corn

		Sorghum-soybean meal		
Ingredient, %	**Corn-soy**	**Option 1**	**Option 2**	**Option 3**
Sorghum	- - -	76.41	80.7	78.59
Corn	77.02	- - -	- - -	- - -
Soybean meal, 46.5%	20.53	21.16	16.54	17.36
Choice white grease	- - -	- - -	- - -	1.30
Monocalcium P, 21% P	0.50	0.425	0.45	0.45
Limestone	0.90	0.95	0.975	0.975
Salt	0.35	0.35	0.35	0.35
Vitamin premix with phystase	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15
Lysine HCl	0.30	0.30	0.45	0.45
DL-Methionine	0.03	0.05	0.095	0.1
L-Threonine	0.075	0.05	0.095	0.1
L-Threonine	0.075	0.05	0.12	0.125
Total	100.00	100.00	100.00	100.00
SID amino acids, %				
Lysine	0.95	0.93	0.93	0.95
Isoleucine:lysine	61	67	59	59
Leucine:lysine	144	155	144	142
Methionine:lysine	29	31	33	33
Met & cys:lysine	56	56	56	56
Threonine:lysine	62	62	62	62
Tryptophan:lysine	17	20	17	17
Valine:lysine	71	75	67	66
Total lysine, %	1.06	1.04	1.03	1.05
ME, kcal/lb	1,517	1,490	1,490	1,517
SID Lysine: ME, g/Mcal	2.84	2.84	2.84	2.84
CP, %	16.5	17.2	15.7	15.9
Ca, %	0.53	0.53	0.53	0.53
P, %	0.46	0.46	0.44	0.44
Available P, %	0.26	0.26	0.26	0.26
Feed budget, lb/pig	100	102	102	100

Feeding Value of Sorghum DDGS

The use of grain sorghum as feedstock for ethanol production has been increasing in recent years and could make a larger contribution to the nation's fuel ethanol requirements. The starch content and ethanol yield from grain sorghum is comparable to that of corn[16]. Currently, about 2.5 percent of fuel ethanol is produced from grain sorghum. However, the annual percentage of sorghum production used for ethanol has steadily increased from 11 percent in 2004 to about 29 percent in 2009[16,17]. The target of the Sorghum Checkoff is to increase the inclusion rate of grain sorghum in ethanol by 50 percent by 2011. These trends indicate that the supply of co-products, such as sorghum dried distillers grains with soluble (DDGS), will increase with the growing demand for grain sorghum used for ethanol production. Currently, research on the feeding value of sorghum DDGS in swine diets is limited. However, available data indicate that sorghum DDGS may offer some advantages compared with corn DDGS for pigs.

"The use of grain sorghum as a feedstock for ethanol production has been increasing in recent years..."

Composition of Sorghum DDGS Compared to Corn DDGS

Chemical Composition

On average, sorghum DDGS has higher crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) as well as lower crude fat than corn DDGS. This is reflective of the differences in the chemical composition of the grain sorghum and corn used to produce ethanol (Table 8). The Ca and total P content of sorghum DDGS are similar to corn DDGS.

Amino Acid Profile

The differences in chemical composition between grain sorghum and corn are also reflected in the amino acid content of sorghum DDGS and corn DDGS (Table 9). On average, sorghum DDGS is higher in total lysine, isoleucine, leucine, phenylalanine and valine but is similar in total arginine, histidine, methionine, threonine and tryptophan compared to corn DDGS.

Currently, research to determine the amino acid digestibility of sorghum DDGS is limited to a single study. The study revealed the SID of lysine in sorghum DDGS and corn DDGS are similar, whereas, the SID values of most other amino acids except isoleucine, threonine, tryptophan and valine are less in sorghum DDGS than in corn DDGS[18] (Table 10). Recent studies also showed that sorghum grain has lower SID of amino acids than corn grain[19-21], which may be a result of higher content of fiber components (NDF, ADF) and lower oil content in sorghum compared to corn. Therefore, sorghum DDGS has higher digestible content of lysine, threonine, tryptophan, isoleucine, leucine, phenylalanine, and valine, similar in arginine, and lower in methionine and histidine compared to corn DDGS.

Table 8. Chemical compostion of sorghum dried distillers grains with solubles (as-fed)

	Proximate analysis, %									
Study	**DM**	**CP**	**Crude fat**	**Crude fiber**	**NDF**	**ADF**	**Ash**	**Ca**	**P**	**Reference**
1	90.0	28.1	10.4	9.4	-	-	4.4	-	-	Senne et al. (1998)Normal endosperm
2	90.9	28.6	10.2	8.8	-	-	5.2	-	-	Senne et al. (1998) Heterowaxy endosperm
3	89.3	25.4	9.7	6.4	-	-	4.4	0.10	0.81	Jenkins (2003) Source 1
4	89.8	30.2	8.9	6.9	-	-	3.5	0.04	0.66	Jenkins (2003) Source 2
5	88.1	30.2	8.5	6.5	-	-	3.8	0.07	0.69	Jenkins (2003) Source 3
6	88.5	29.8	7.9	7.9	-	-	3.5	-	0.62	Feoli et al. (2007a) Oakley
7	88.1	30.5	7.3	6.4	-	-	3.7	-	0.66	Feoli et al. (2007a) Russell
8	89.2	30.4	7.0	5.3	29.1	10.1	3.6	0.08	0.65	Feoli et al. (2007b) Russell Exp. 1
9	89.6	30.5	6.8	6.3	29.6	10.4	3.7	0.09	0.65	Feoli et al. (2007b) Russell Exp. 2
10	90.0	29.5	7.0	-	29.1	10.1	3.6	-	-	Feoli et al. (2008) Russell Exp. 1
11	90.8	31.1	83	-	29.7	10.5	3.7	-	-	Feoli et al. (2008) Russell Exp. 2
12	90.4	28	8.6	-	26.9	9.6	3.5	-	-	Feoli et al. (2008) Russell Exp. 3
13	883	30.7	10.2	7.2	29.6	19.2	4.1	0.04	0.72	Jones et al. (2009) Source 1
14	88.4	29.7	8.9	6.9	28.2	20.3	3.9	0.07	0.69	Jones et al. (2009) Source 2
15	91.2	32.7	8.0	-	34.7	25.3	11.9	-	-	Urriola et al. (2009)
n	15	15	15	11	8	8	15	7	9	
Ave[1]	**89.5**	**29.8**	**8.5**	**7.0**	**29.2**	**13.4**	**3.9**	**0.07**	**0.67**	
Corn										
DDGS	87.6	27.4	10.1	7.8	25.3	9.9	3.8	0.07	0.67	

[1]Average values were calculated by taking the mean of the values excluding the highest and lowest value.

Table 9. Amino acid content of sorghum dried distillers grains with solubles (as-fed)

	Total amino acids, %												
							Met						
Study	**Arg**	**His**	**Ile**	**Leu**	**Lys**	**Met**	**+Cys**	**Phe**	**+Tyr**	**Thr**	**Trp**	**Val**	**Reference**
1	1.11	0.71	1.46	4.27	0.76	- - -	0.96	- - -	2.92	1.14	0.23	1.75	Senne et al. (1998) Normal endosperm
2	1.20	0.71	1.42	4.16	0.86	- - -	1.01	- - -	2.87	1.18	0.25	1.76	Senne et al. (1998) Hetero-waxy endosperm
3	1.22	0.72	0.96	2.79	0.89	0.49	1.03	1.27	2.21	0.93	0.24	1.34	Jenkins (2003) Source 1
4	1.23	0.79	1.25	4.03	0.89	0.56	1.18	1.64	2.86	1.08	0.21	1.60	Jenkins (2003) Source 2
5	1.7	0.72	1.25	3.86	0.84	0.49	1.07	1.60	2.78	1.03	0.22	1.58	Jenkins (2003) Source 3
6	1.29	0.77	1.25	3.93	0.95	0.58	1.16	1.46	2.59	1.09	0.20	1.67	Jones et al. (2009) Source 1
7	1.15	0.70	1.25	3.92	0.84	0.50	1.02	1.42	2.50	1.03	0.19	1.62	Jones et al. (2009) Source 2
8	1.10	0.71	1.36	4.17	0.68	0.53	1.02	1.68	- - -	1.07	0.35	1.65	Urriola et al. (2009)
n	8	8	8	8	8	6	8	6	7	8	8	8	
Ave[1]	**1.18**	**0.72**	**1.30**	**4.01**	**0.85**	**0.52**	**1.06**	**1.53**	**2.72**	**1.08**	**0.23**	**1.64**	
Corn													
DDGS	1.14	0.71	1.00	3.11	0.76	0.54	1.06	1.32	2.32	1.04	0.21	1.34	Stein and Shurson (2009)

[1]Average values were calculated by taking the mean of the values excluding the highest and lowest value.

Table 10. Standardized ileal digestibility (SID, %) of CP and amino acids in corn and sorghum dried distillers grains with solubles

	SID, %	
Item	**Corn-DDGS[1]**	**Sorghum-DDGS[2]**
Arg	81.1	79.2
His	77.1	71.9
Ile	75.3	74.0
Leu	83.5	77.3
Lys	60.6	64.0
Met	81.8	76.5
Phe	80.8	76.9
Thr	70.4	70.2
Trp	69.6	72.0
Val	74.4	73.6

[1]Stein and Shurson (2009).
[2]Urriola et al. (2009).

"One of the keys to unlocking sorghum's nutritional value is proper feed processing."

Energy Value

Gross energy (GE) of sorghum DDGS is similar to corn DDGS. However, GE digestibility is lower in sorghum DDGS. A recent review reported the apparent total tract digestibility for GE of corn DDGS ranged from 73.9 to 82.8 percent, with an average of 76.8 percent[22]. The average GE digestibility of sorghum DDGS was 74 percent, which is lower than the average but within the range for corn DDGS (Table 11). Lower energy digestibility in sorghum DDGS may be due to its greater concentration of fiber components compared to corn DDGS. Both digestible and metabolizable energy of sorghum DDGS was lower than corn DDGS, which is 96 percent of the values for corn DDGS. This reflects the same difference in energy value between grain sorghum and corn.

Available Phosphorus

One of the advantages of using corn DDGS in diet formulations is its higher phosphorus content and phosphorus bioavailability compared to corn grain. Like corn DDGS, the concentration of phosphorus in sorghum DDGS is greater than grain sorghum, ranging from 0.62 to 0.81 percent. The bioavailability of phosphorus in corn DDGS is about 70 to 90 percent relative to dicalcium phosphate[23-24]. The apparent total tract digestibility of phosphorus in corn DDGS ranges from 50 to 68 percent, which is about 59 percent on average[22]. However, data on phosphorus bioavailability in sorghum DDGS is limited. One study evaluated phosphorus utilization in sorghum DDGS in growing pigs using both the slope ratio assay and digestibility study[25]. phosphorus bioavailability values from the slope ratio assay were 80 percent relative to monosodium phosphate for one source of sorghum DDGS and 60 percent for

two other sources. The apparent total tract digestibility of phosphorus for the three sources of sorghum DDGS ranged from 57 to 58 percent. Overall, sorghum DDGS had greater phosphorus bioavailability compared to grain sorghum. Though more research is needed, phosphorus bioavailability in sorghum DDGS may be similar to corn DDGS.

Fatty Acid Profile

Nearly 50 percent of the fatty acids in sorghum DDGS is linoleic acid (C18:2n6)[26]. Other major fatty acids in sorghum DDGS is oleic acid (C18:1n6; 28 percent) and palmitic acid (C16:0; 17 percent). This is to be expected as linoleic acid comprises 28 to 51 percent of the fatty acids in oil obtained from sorghum[27]. However, linoleic acid content of corn oil ranges from 40 to 70 percent of the total fatty acids[28] and, with the higher fat content in corn DDGS, it may have greater effects on carcass fat iodine value than using sorghum DDGS. Therefore, when added to finishing diets, sorghum DDGS may be included at higher rates compared to corn DDGS with less effect on carcass fat quality.

In summary, the differences in the nutrient composition of sorghum and corn DDGS is similar to the differences between grain sorghum and corn. Sorghum DDGS is higher in CP and digestible lysine, threonine, tryptophan, and valine content, similar in available phosphorus, and lower in crude fat and digestible methionine than corn DDGS. Like sorghum grain compared to corn grain, the energy value of sorghum DDGS is about 96 percent of corn DDGS. It is high in polyunsaturated fatty acids like corn DDGS, but it should have a lesser effect on carcass fat iodine value compared to corn DDGS due to its lower linoleic acid content. With proper diet formulation, sorghum DDGS can be used as effectively as corn DDGS in swine diets.

Table 11. Energy concentrations in corn and sorghum dried distillers grains with solubles (as-fed)

Item	Corn-DDGS[1]	Sorghum-DDGS[2,3]
Gross energy, kcal/lb	2,160	2,142
Digestible energy, kcal/lb	1,645	1,585
Metabolizable energy, kcal/lb	1,549	1,491

[1]Pedersen et al. (2007).

[2]Gross energy value is the mean of 11 reported values excluding the highest and lowest value; Senne et al. (1996), Feoli et al. (2007a), Feoli et al. (2007b), Feoli et al. (2008)

[3]Digestible energy = gross energy x 74%; ME = DE x [1.003-(0.0021 x % CP)].

Review of Feeding Trials with Sorghum DDGS

Nursery Pigs

A total of five experiments evaluated the effects of including sorghum DDGS in nursery diets[29-32] (Table 12). Overall, sorghum DDGS included up to 30 percent of the diet did not affect ADG, ADFI and G:F of weanling pigs fed diets without sorghum DDGS. One research study observed quadratic reductions in ADG and G:F of nursery pigs fed diets with 0, 15, 30, 45 and 60 percent sorghum DDGS[30]. These mainly resulted from a linear reduction in ADFI as inclusion of sorghum DDGS increased. However, most of the negative effects were observed at 45 and 60 percent inclusion of sorghum DDGS. Two studies compared the growth performance of nursery pigs fed diets with 30 percent corn or sorghum DDGS. The first study showed that pigs fed sorghum DDGS had similar ADG but had higher ADFI and lower G:F than pigls fed corn DDGS[32]. The higher ADFI observed in this study may be a result of the lower energy content in sorghum DDGS relative to corn DDGS. In contrast, the second study showed greater ADG and ADFI in piglets fed sorghum DDGS[31]. As with corn DDGS, the differences in results may be attributed to the variability in quality of different sorghum DDGS sources. In summary, sorghum DDGS can be used up to 30 percent of the diet without impairing growth performance of nursery pigs.

"Studies showed that sorghum DDGS can be fed as high as 30 percent without negative effects on growth performance."

Growing-Finishing Pigs

A number of studies evaluated the effects of including sorghum DDGS in growing-finishing diets[29-31, 33-36] (Table 13). In the first experiment, sorghum DDGS was added at 0, 10, 20 and 30 percent of the diet fed to growing-finishing pigs and showed no differences in growth performance[29]. In another study, feeding sorghum DDGS from 0 to 60 percent of diets resulted in linear reductions in ADFI but did not affect ADG of finishing pigs[30]. As a result, a linear improvement in G:F was observed with increasing sorghum DDGS. However, in recent studies, feeding 40 percent sorghum DDGS to finishing pigs reduced ADG, ADFI and G:F compared to pigs fed a typical corn-soy diet[31,33,35-36]. One study compared the growth performance of finishing pigs fed 40 percent corn or sorghum DDGS[31]. Results showed similar ADG but greater ADFI and lower G:F in pigs fed sorghum DDGS. The higher ADFI may be a response to the lower energy content of sorghum DDGS compared to corn DDGS.

Recent studies also evaluated carcass traits and showed that feeding sorghum DDGS to finishing pigs at 40 percent of the diet resulted in lower hot carcass weight but did not affect dressing percentage, lean percentage, backfat thickness and loin depth[35-36]. In terms of carcass fat quality, sorghum DDGS in finishing diets resulted in greater jowl fat iodine value and worse belly firmness scores than pigs fed diets without sorghum DDGS[35-36]. This is to be expected, as sorghum DDGS is high in polyunsaturated fatty acids.

Table 12. Growth performance of nursery pigs fed sorghum dried distillers grains with solubles

	BW	No. of	Criteria	Sorghum-DDGS, % of diet							
Study	(lb)	pigs	(lb)	0	10	15	20	30	45	60	Reference
1	15 to 40	72	ADG	1.02	1.06	- - -	1.01	- - -	- - -	- - -	Senne et al. (1995)
			ADFI	1.64	1.71	- - -	1.76	- - -	- - -	- - -	
			G:F	0.62	0.62	- - -	0.58	- - -	- - -	- - -	
2	13 to 33	180	ADG	1.07	- - -	1.10	- - -	1.02	0.88	0.71	Senne et al. (1996)
			ADFI	1.72	- - -	1.62	- - -	1.43	1.42	1.28	
			G:F	0.62	- - -	0.68	- - -	0.72	0.61	0.55	
3	17 to 50	72	ADG	1.27	- - -	- - -	- - -	1.20	- - -	- - -	Feoli et al. (2008a)
			ADFI	1.82	- - -	- - -	- - -	1.80	- - -	- - -	
			G:F	0.70	- - -	- - -	- - -	0.67	- - -	- - -	
4	24 to 27	350	ADG	1.05	- - -	- - -	1.07	1.01	- - -	- - -	Jones et al. (2009)
			ADFI	1.60	- - -	- - -	1.68	1.65	- - -	- - -	Source 1
			G:F	0.66	- - -	- - -	0.64	0.61	- - -	- - -	
5	24 to 27	350	ADG	1.05	- - -	- - -	1.05	1.02	- - -	- - -	Jones et al. (2009
			ADFI	1.60	- - -	- - -	1.68	1.68	- - -	- - -	Source 2
			G:F	0.66	- - -	- - -	0.63	0.61	- - -	- - -	

Table 13. Growth performance of growing-finishing pigs fed sorghum dried distillers grains with solubles

Study	BW (lb)	No. of pigs	Criteria (lb)	Sorghum-DDGS, % of diets						Reference
				0	10	20	30	40	60	
1	94 to 192	192	ADG	1.97	1.98	1.93	1.93	- - -	- - -	Senne et al. (1995)
			ADFI	5.22	5.19	4.98	5.08	- - -	- - -	
			G:F	0.38	0.38	0.39	0.38	- - -	- - -	
2	120 to 246	80	ADG	2.09	- - -	2.22	- - -	2.22	2.19	Senne et al. (1996)
			ADFI	6.97	- - -	6.75	- - -	6.66	6.38	
			G:F	0.30	- - -	0.33	- - -	0.33	0.34	
3	143 to 248	192	ADG	1.96	- - -	- - -	- - -	1.84	- - -	Senne et al. (1998)
			ADFI	7.00	- - -	- - -	- - -	7.38	- - -	
			G:F	0.28	- - -	- - -	- - -	0.25	- - -	
4	141 to 287	88	ADG	2.08	- - -	- - -	- - -	2.00	- - -	Feoli et al. (2007a)
			ADFI	6.93	- - -	- - -	- - -	7.15	- - -	
			G:F	0.30	- - -	- - -	- - -	0.29	- - -	
5	158 to 287	56	ADG	2.12	- - -	- - -	- - -	1.96	- - -	Feoli et al. (2007b)
			ADFI	7.34	- - -	- - -	- - -	6.98	- - -	
			G:F	0.29	- - -	- - -	- - -	0.28	- - -	
6	141 to 284	132	ADG	2.14	- - -	- - -	- - -	1.96	- - -	Feoli et al. (2008a)
			ADFI	6.71	- - -	- - -	- - -	6.43	- - -	
			G:F	0.32	- - -	- - -	- - -	0.30	- - -	
7	150 to 271	56	ADG	1.80	- - -	- - -	- - -	1.69	- - -	Feoli et al. (2008b)
			ADFI	6.32	- - -	- - -	- - -	6.07	- - -	
			G:F	0.28	- - -	- - -	- - -	0.28	- - -	

Table 14. Example diets with grain sorghum DDGS replacing corn DDGS

	10% DDGS diets			20% DDGS diets		
	Corn	Sorghum DDGS		Corn	Sorghum DDGS	
Ingredient, %	**DDGS**	**Option 1**	**Option 2**	**DDGS**	**Option 1**	**Option 2**
Corn	68.92	69.37	68.90	61.04	61.93	60.91
Soybean meal, 46.5%	18.62	18.19	18.41	16.70	15.84	16.28
Sorghum DDGS	- - -	10	10	- - -	20	20
Corn DDGS	10	- - -	- - -	20	- - -	- - -
Choice white grease	- - -	- - -	0.25	- - -	- - -	0.60
Monocalcium P, 21% P	0.30	0.25	0.25	0.10	0.05	0.05
Limestone	1.125	1.15	1.15	1.125	1.15	1.15
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix with phytase	0.15	0.15	0.15	0.15	0.15	0.15
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15
Lysine HCl	0.325	0.325	0.325	0.35	0.35	0.35
DL-Methionine	- - -	0.01	0.01	- - -	- - -	- - -
L-Threonine	- - -	0.01	0.01	- - -	- - -	- - -
Total	100.00	100.00	100.00	100.00	100.00	100.00
SID amino aicds, %						
Lysine	0.95	0.95	0.95	0.95	.094	0.95
Isoleucine:lysine	63	65	65	65	69	69
Leucine:lysine	158	162	162	171	181	179
Methionine:lysine	28	28	28	30	29	29
Met & cys:lysine	57	57	57	62	59	59
Threonine:lysine	62	62	62	62	62	60
Tryptophan:lysine	17	17	17	17	17	17
Valine:lysine	74	76	76	78	82	81
Total lysine, %	1.08	1.07	1.08	1.09	1.08	1.10
ME, kcal/lb	1,517	1,512	1,517	1,521	1,509	1,521
SID Lysine:ME, g/Mcal	2.84	2.84	2.84	2.83	2.83	2.83
CP, %	17.6	17.7	17.8	18.8	18.9	19.1
Ca, %	0.57	0.57	0.57	0.53	0.53	0.53
P, %	0.45	0.44	0.44	0.43	0.43	0.43
Available P, %	0.26	0.26	0.26	0.26	0.26	0.26
Feed budget, lb/pig	100.0	100.4	100.0	99.8	100.5	99.7

In summary, studies for both nursery and growing-finishing pigs showed that sorghum DDGS can be fed as high as 30 percent of the diet without negative effects on growth performance or carcass characteristics. In finishing pigs, effects on carcass fat quality should be considered especially when higher concentrations of sorghum DDGS are used in the diet. Research is needed to determine the feeding value of sorghum DDGS in sows.

Feeding Recommendations for Sorghum DDGS

Example diets where sorghum DDGS replaced corn DDGS at 10 and 20 percent of the diet are shown in Table 14. In Option One, sorghum DDGS replaced corn DDGS at an equal weight basis, with only a small reduction in ME content of the diet. Option Two shows the diet formulation when fat was added to equalize the ME content of diets with sorghum and corn DDGS. It shows that only a small percentage of fat was needed to bring the sorghum DDGS diets to an equal ME level as the corn DDGS diets. Therefore, sorghum DDGS can be used at the same inclusion rates as corn DDGS in swine diets.

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When determining the value of your feedstuffs it is important to remember:

- ***Sorghum DDGs are naturally darker in color and have excellent nutritional value.***
- ***Color only matters when you don't know the nutritional value of your dry distillers grain product.***
- ***You should ask your distillers marketer for your dry distillers grain nutritional facts.***

SORGHUM CHECKOFF SM

United Sorghum Checkoff Program