Effect of DDGS source on growth performance and carcass characteristics of growing-finishing pigs

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ABSTRACT

Distiller's dried grains with solubles (DDGS) is quite variable in nutritional content and quality among different sources. As a result, DDGS inclusion in swine diets has resulted in different growth performance responses. The objective of this study was to evaluate the effects of feeding diets containing three DDGS sources differing in quality to growing-finishing pigs on growth performance and carcass characteristics. A total of 448 pigs with initial weight of 62.7 kg, were allotted to one of 14 pens, with genders housed separately (7 barrow pens and 7 gilt pens), and were fed one of 4 dietary treatments in a 2-phase feeding program. Pigs were fed to final body weight of 115.8 kg before harvest. Diets consisted of a corn-soybean (SBM) control diet (CON), 20% DDGS from a high digestible lysine source (HDDGS), 20% DDGS from a mid range lysine digestibility source (MDDGS) and 20% from a low digestible lysine source (LDDGS). Diets were formulated on a digestible amino acid basis to contain equal levels of digestible lysine by adjusting the amount of SBM in the diet, and all diets contained 0.15% L-lysine HCL. Diets were formulated using NRC (1998) digestibility values for corn and SBM, and source specific DDGS amino acid digestibility values that were determined in a previous research study. Pigs had *ad libitum* access to feed and water throughout the trial. Overall ADG was decreased for pigs fed LDDGS (0.96 kg/d, $P < 0.05$) compared to the control diet (1.00 kg/d). However, ADG of pigs fed HDDGS and MDDGS were not different from pigs fed the control diet. Pigs fed HDDGS and LDDGS had lower ADFI than CON (2.83 and 2.84 kg/d, respectively, $P < 0.05$). Overall G:F was higher for HDDGS than CON, but there were no differences among other dietary treatments. Water disappearance and water:feed ratio was measured in 6 pens per dietary treatment and did not differ among treatments. There were no differences in final BW among the dietary treatments. Dressing % for pigs fed HDDGS and MDDGS was reduced ($P < 0.05$) compared to CON, but not for LDDGS. Last rib backfat depth was reduced ($P < 0.05$) for pigs fed HDDGS compared to CON but not for the other treatments. There were no differences in % carcass lean, loin depth, or 10^{th} rib backfat thickness among any of the dietary treatments. These results suggest that DDGS sources of lower quality may reduce pig performance, while higher quality sources did not. Quality and variation in nutrient content among DDGS sources should be considered when adding it to growing-finishing swine diets.

INTRODUCTION

There are over 130 ethanol production facilities in operation and over 60 more under construction, most of which produce ethanol from corn (RFA, 2008). As demand for corn by the ethanol industry increases and corn prices rise, pork producers and swine nutritionists need to look for lower cost alternative ingredients to minimize diet cost.

While increases in ethanol production decrease the corn supply available for livestock feed, ethanol production may also be part of the solution to higher corn prices because the supply of distiller's dried grains with solubles (DDGS) produced also increases. The supply of DDGS provides an opportunity for livestock producers to partially replace some of the corn, SBM, and inorganic phosphorus in swine diets and possibly reduce diet cost. Many growing-finishing swine diets contain 10% DDGS and have resulted in pig performance equal to that achieved when feeding a typical corn-SBM diet with some diet cost savings. At higher levels of DDGS inclusion, ADG and ADFI responses have been inconsistent. If growing-finishing swine diets can include 20% DDGS and achieve the same pig performance as corn-SBM diets, the cost savings to pork producers can be even greater than that achieved when using it at the 10% DDGS inclusion level.

Nutrient content and lysine digestibility are quite variable among sources of DDGS as shown in several published reports (Cromwell et al., 1993; Spiehs et al., 2002; Shurson et al., 2004; Stein et al., 2006; Urriola et al., 2007). This may be one of the reasons for reduced ADG and ADFI when feeding higher dietary inclusion levels of DDGS. Because of the high variability in amino acid digestibility, particularly lysine, it is important that swine diets containing DDGS be formulated on a digestible amino acid basis. There is no current work comparing the effects of feeding diets containing different sources of DDGS on growth performance and carcass characteristics of grower-finisher pigs in the same study. Therefore, the objective of this study was to determine the effects of feeding diets containing 20% DDGS from different sources that vary in digestible lysine content to growing-finishing pigs on growth performance and carcass characteristics.

MATERIALS AND METHODS

Animals and Housing

Prior to initiation of the study, the experimental protocol was approved by the University of Minnesota Institutional Animal Care and Use Committee. A total of 448 pigs (224 barrows and 224 gilts) were housed in an environmentally controlled wean-to-finish facility at the University of Minnesota's Southern Research and Outreach Center in Waseca, MN. Pigs used in this experiment were terminal offspring of sows (Landrace X Yorkshire) from Genetically Advanced Pigs (Winnipeg, MB) sired by Duroc boars from Compart's Boar Store (Nicollet, MN). Pigs were housed in 56 pens measuring 2.0 m x 3.0 m with 8 pigs per pen. Barrows and gilts were housed separately resulting in 7 replications of each gender per dietary treatment. Each pen contained a 2-hole stainless steel self-feeder and a nipple drinker in a watering bowl. Pigs were allotted to one of four dietary treatments blocked by weight and gender in a completely randomized design 2 months prior to the beginning of the trial, and all pigs were fed a common corn-SBM control diet prior to the beginning of the experiment. When the experiment began, pigs were fed one of four dietary treatments in a 2-phase grower-finisher feeding program (50-80 kg, and 80-120 kg). Pigs were allowed *ad libitum* access to feed and water throughout the trial and were monitored for health.

Dietary Treatments

Diets within each phase were formulated to contain equivalent levels of standardized ileal digestible (SID) lysine and similar levels of ME, vitamins, and minerals (Tables 1 and 2). All diets were formulated to meet or exceed recommended nutrient levels for 350 g/d lean gain pigs (NRC 1998). Values for SID amino acids of the DDGS sources used were obtained form Urriola et al. (2007), and the amino acid content of these sources was determined by analyzing the specific lot of each of the three DDGS sources fed (Table 3). Corn and SBM (48% CP) SID amino acid values used in the formulation of the experimental diets were obtained from NRC (1998). The control diet was a typical corn-SBM based diet containing 0.15% synthetic lysine. The experimental diets all contained 20% DDGS, each originating from one of three different ethanol plants that differed in nutrient content and amino acid digestibility. The HDDGS diet contained DDGS with the highest CP content (29.5%) from a high quality source, defined by having a high amount of digestible lysine (SID Lys = 0.68%). The MDDGS diets included a DDGS source intermediate in CP (28.6%) with a SID lysine content of 0.60%. The LDDGS diets contained a DDGS source that was the lowest in CP (27.6%) and had a SID lysine level of 0.52%.

Diets were formulated using L-lysine HCl addition in phase 1 diets and phase 2 experimental diets contained 0.01% synthetic tryptophan as well as L-lysine HCl to meet the recommended NRC (1998) ratios for tryptophan:lysine while minimizing the amount of SBM inclusion in the diets. In the experimental DDGS diets, L-lysine HCL was fixed at the same inclusion level as the control diet (0.15%), and corn and SBM were adjusted in these diets to contain equal levels of SID lysine among the dietary treatments within each phase. Because of the differing levels of SBM included in the experimental diets, the diets utilizing the DDGS source having the highest level of SID lysine had the least amount of SBM and resulted in a lower CP level than the other DDGS diets that contained DDGS sources with less digestible lysine and higher levels of SBM.

Diets containing DDGS included less dicalcium phosphate than CON because of the high level and high availability of phosphorus (Whitney and Shurson, 2001; Pedersen et al., 2007; Jenkin et al., 2007) in DDGS. Because reducing dicalcium phosphate also reduced the calcium level of DDGS diets, limestone was added to maintain proper calcium levels. Values used for available phosphorus were those reported by NRC (1998) for corn, SBM, and dicalcium phosphate, and a 90% relative phosphorus availability for DDGS as reported by Whitney and Shurson (2001) was used. Dietary calcium:phosphorus ratios were maintained at levels between 1:1 and 2:1 in all diets as recommended by NRC (1998), and ratios of calcium:available phosphorus were formulated to be between 2:1 and 3:1 as recommended by NRC (1998). Some diets contained calcium:available phosphorus ratios higher than 3:1, which was a result of analyzed calcium values being higher than the calculated values the diets were formulated to contain.

Feed samples were obtained from each batch of feed manufactured and frozen at −20° C until laboratory analysis was performed. At the end of the study, samples from each batch of feed were combined within experimental diet and phase. These pooled samples were subsampled for nutrient analysis. A portion of this subsample was submitted for proximate and mineral analysis at Minnesota Valley Testing Laboratories (New Ulm, MN). Another portion of the subsample was submitted for amino acid analysis by HPLC procedures (Experiment Station Chemical Laboratory, University of Missouri, Columbia). A sample of each DDGS source was analyzed prior to, and at the conclusion of the study using the same procedures used for chemical analysis of experimental diets. Nutrient values of DDGS sources used in diet formulations are shown in Table 3, and the same lot of DDGS from each source was fed throughout the experiment.

Measurements

Pig body weight and pen feed disappearance were measured at the conclusion of each phase and every 2 wks to determine ADG, ADFI and G:F. Dietary phase changes were made on the same day, and at that time that all individual pen average body weights were within 4.5 kg of the targeted phase break. Coefficient of variation (CV) of body weights within each pen was calculated at the beginning and end of the study to determine if feeding DDGS diets affect body weight variation within pens. Pigs were marketed in 3 groups, based on body weight at the time of harvest. All growth performance data are reported to a common end date when the first group of pigs was marketed. Target market weight was 125 kg, and pigs were kept on their respective experimental diets for the duration of the study until they were shipped for harvest.

Water disappearance measurements were determined in a subset of 24 pens, with 6 pens per dietary treatment (3 barrow and 3 gilt pens). Pen water disappearance was measured with an AMCO C700 5/8” positive displacement meter (Elster AMCO Water Inc., Ocala, FL) installed in the pipeline in each of the 24 pens fitted with a water meter. One of the water meters located in a pen of barrows fed the MDDGS treatment did not function properly and water meter readings were not used for this pen during the entire study, resulting in a total of 23 pens with water measurements. Pen water disappearance was used to calculate the average daily water disappearance (ADWD) as well as water:feed intake ratio (W:F) which was calculated using feed intake data from each respective pen.

The experiment involved feeding a total of 448 pigs at the beginning of the study and 444 pigs remained at the conclusion of the study. Two pigs died during the course of the study. A gilt from LDDGS treatment was euthanized because of lameness and a gilt from HDDGS died due to an unknown cause. Two more pigs, a gilt from CON and a barrow from LDDGS were removed from the study because of morbidity.

When pigs reached harvest weight (approximately 125 kg) they were marketed in three separate groups, each group was harvested the following day at a large commercial abattoir in the Midwestern U.S. Final body weights correspond to the day the first group was shipped to harvest were used to calculate growth performance responses. Of the 444 pigs harvested, carcass data were obtained from 412 carcasses because some carcasses could not be located in the plant. Since pigs were marketed according to the target harvest weight, the harvest weights and hot carcass weight measurements reported do not reflect growth rate responses throughout the trial. Last rib backfat thickness and hot carcass weight were determined on the slaughter line by plant personnel. Last rib backfat thickness was measured at the midline after the skin was removed and adjusted to a skin-on basis by adding 2.54 mm (NPPC, 2000) to the measured fat depth of each carcass. The reported hot carcass weights are adjusted to a skin-on basis based on within plant adjustment procedures to account for skin removal. Percentage of fat-free lean in the carcass was estimated using 10^{th} rib backfat depth and loin muscle depth in the following equation {58.85 +[(-0.61 x 10^{th} rib backfat depth, mm) + (0.12 x loin depth, mm) according to Whitney et al. (2006).

Statistical Analysis

Pig performance and carcass composition data were analyzed as a randomized complete block design using the Mixed Procedure of SAS 9.1 (SAS Inst. Inc., Cary, NC). The pen was used as the experimental unit for these analyses. The statistical model included fixed effects of dietary treatment, gender, dietary treatment x gender interaction, and block as a random effect. Analysis of pig performance included ADG, ADFI, G:F, average daily water disappearance, and water:feed ratio for overall measurements. Initial weight was used as a covariate in analysis of overall ADG and ADFI. Repeated measures in time were used to analyze data by diet phase. Unstructured (UN) model was used to fit the variance-covariance matrix determined by the Akaike information criterion and Schwarz Bayesian criterion and UN was considered to be the most desirable structure (Littell et al., 2006). Carcass characteristics measured included hot carcass weight, 10^{th} rib backfat depth, % carcass lean, and individual pig was the experimental unit for these analyses. Harvest date was used as a covariate for dressing percentage data analysis because this was the only measurement in which the covariate was significant. All means are reported as least squares means. The alpha level used for determination of significance for all analyses was set at 0.05. When the P-value was $0.10 > P > 0.05$, statistical trends are reported in the text.

RESULTS & DISCUSSION

In this study, growth performance differed between barrows and gilts with the barrows having a higher ADG ($P < 0.001$) and ADFI ($P < 0.001$) and a lower G:F ratio ($P < 0.03$) than gilts (Table 4). These gender effects on growth performance were consistent with previous findings (Elkstrom et al., 1991; Friesen et al., 1994; Hahn et al., 1995; Cisneros et al., 1996; Chen et al., 1999; Cline and Richert, 2000; Wiseman et al., 2007) in which barrows have a higher ADFI, ADG, and lower G:F than gilts. For overall growth performance responses, there was no significant diet x gender interactions for any of these growth performance measurements.

Growth Performance by Dietary Phase

During phase 1, barrows had a higher ($P < 0.05$) ADG, ADFI and lower G:F than gilts. However, there were no differences in ADG, ADFI and G:F among treatments for phase 1. In phase 2, barrows had a higher ADG and ADFI than gilts, however G:F was similar for both genders. None of the dietary treatments were different for ADG, but ADFI for CON was higher than HDDGS ($P < 0.01$), and tended to be higher than MDDGS and LDDGS ($P = 0.08$ and $P = 0.09$, respectively). There were no significant differences in ADFI or G:F for any of the other dietary treatments.

Overall Growth Performance

Overall ADG was similar for pigs fed CON, HDDGS, and MDDGS diets. However, pigs fed CON had a higher ADG ($P < 0.05$) than the LDDGS diet. Overall ADFI was similar for CON and MDDGS, yet pigs fed HDDGS and LDDGS had ADFI that was less than pigs fed CON. Heat damage can contribute to differences in Lys digestibility of DDGS (Pahm et al., 2008) and the LDDGS source could have experienced heat damage, decreasing the lysine digestibility compared to what was previously reported for this source. These differing results are similar to results reported in the literature where feeding diets containing 20% DDGS or higher inclusion levels to growing-finishing pigs have led to inconsistent responses on pig performance. Studies showing similar (Wahlstrom et al., 1970; Cook et al., 2005; DeDecker et al., 2005; Widmer et al., 2007; Xu et al., 2007) and reduced (Fu et al., 2004; Whitney et al., 2006; Hinson et al., 2007; Linneen et al., 2007; Widyaratne and Zijlstra, 2007) growth performance have been reported when comparing pig performance when feeding DDGS diets to control diets. These inconsistent results could be due to variation in the DDGS quality or overestimation of amino acid digestibility in DDGS. Results from this study show that there are growth performance differences when feeding the same level of DDGS, but from different sources to growing-finishing pigs.

In many cases, the decrease in ADG observed in this study was a result of decreased ADFI. It is unclear why ADFI decreases in some studies and not others, but it may be due to palatability differences among DDGS sources (Hastad et al., 2005). Palatability of the DDGS source may not be related to DDGS quality and nutrient content because in this experiment, ADFI was reduced when pigs were fed the HDDGS and LDDGS diets but not the MDDGS diets. Crude protein content of the experimental diets was different due to more SBM being added to diets containing DDGS sources lower in digestible lysine in order to maintain equal lysine levels. Chen et al. (1999) reported that diets containing high levels of DDGS resulted in reduced ADFI and ADG. However, in our study, ADFI was reduced when pigs were fed diets containing the highest and lowest crude protein content and not for the diet containing an intermediate level of crude protein. Increased dietary sulfur content has been shown to reduce ADFI and ADG in ruminant diets (Zinn et al., 1997) and DDGS is higher in sulfur than other feed ingredients commonly used in swine diets. However, the DDGS sources used in this study were similar in sulfur content and likely was not a contributing factor to the reduction in ADFI observed when feeding the HDDGS and LDDGS diets.

All diets had similar G:F, with the exception of the HDDGS which had an increased G:F compared to CON. Increased dietary fat content improves feed efficiency and reduces ADFI (Pettigrew and Moser, 1991; De la Llata et al., 2001). In this study, the reduction in ADFI and improvement in feed efficiency observed with the HDDGS diet may have been due to the higher fat content of diets containing DDGS. Xu et al. (2007) also reported an increase in G:F of pigs fed DDGS, with ADG similar to the control diet and a decrease in ADFI. However, these differences were not observed for either the MDDGS or LDDGS diets. Final BW was not different among any of the dietary treatments ($P = 0.15$). This was likely caused by small differences in initial body weight, because different final body weights would be expected due to differences in ADG. The CV of final body weight was similar for all treatments with the exception of pigs fed LDDGS having a lower CV compared to CON. This difference may be partially explained by the CV of initial BW being lower for pigs fed LDDGS. Differences in some pig performance measurements showed that when compared to CON, different DDGS sources will result in different growth performance responses. The sources varied in lysine digestibility, but also varied in crude protein content. However, each DDGS source fed in this study had a Lys:crude protein ratio above 2.80 as recommended by Stein (2007) and would be considered to be high quality sources of DDGS. Dietary inclusion of DDGS at 20%, which are the maximum recommended levels by Shurson et al. (2004) and Stein (2007) in growing-finishing swine diets, appear to support similar growth performance as when pigs are fed a corn and SBM diet when feeding the high and medium lysine digestibility DDGS sources used in this study.

Water Disappearance

Pen water disappearance data by dietary treatment are shown in Table 4 and are reported on a per pig basis, but did not differ among the dietary treatments. Also, water intake adjusted for feed intake, reported as the water:feed ratio, was not different among any of the dietary treatments. There were no differences for water intake by gender for either average daily water disappearance or water:feed ratio, but gilts fed LDDGS diets had a tendency for a higher average daily water disapearance than gilts on CON diets ($P = 0.09$). Diets contained similar, but not equal levels of salt, and this could have impacted water intake (Hagsten and Perry, 1976). Feeding DDGS diets may increase water consumption because they contain more dietary crude protein than CON diet, and feeding diets high in crude protein have resulted in increased water consumption (Thulin and Brumm, 1991; Shaw et al., 2006).

Carcass Characteristics

Carcass characteristics differed between genders for many traits, with barrows having a higher harvest weight, hot carcass weight, last rib backfat depth, 10^{th} rib backfat depth, but a decreased loin depth and percentage carcass lean than gilts (Table 5). These results are similar to those reported by Bereskin and Davey (1978), Uttaro et al. (1993), and Friesen et al. (1994). Dressing percentage was not significantly different for barrows and gilts in this study. There were no significant diet x gender interactions for any of the carcass characteristics measured in this study.

Since pigs were marketed in three groups corresponding to target harvest weight, the harvest body weights were similar among dietary treatments. Differences in hot carcass weights were observed among dietary treatments with pigs fed HDDGS and MDDGS treatments having reduced hot carcass weight ($P < 0.05$) compared to CON. Because there were differences in hot carcass weights in the study, there also were differences in carcass dressing percentage, with pigs fed the CON and LDDGS diets having similar dressing percentage, but a higher dressing percentage than pigs fed the HDDGS and MDDGS treatments. A reduction on dressing percentage has been observed on an inconsistent basis in diets containing DDGS diets. Some studies have shown a decrease in dressing percentage when feeding diets containing DDGS (Whitney et al., 2006; Feoli et al., 2007; Gaines et al., 2007a,b; Xu et al., 2007), while others have not (Fu et al., 2004; Cook et al., 2005; Widmer et al., 2007). The decrease in dressing percentage observed in some studies when feeding DDGS diets has been hypothesized to be the result of higher crude protein and fiber levels. High dietary crude protein levels have been shown to increase weights of visceral organs, resulting in a decreased dressing percentage (Pond et al., 1989; Chen et al., 1999; Barea et al., 2006). In this study, pigs fed LDDGS did not have a reduced dressing percentage, while pigs fed the MDDGS and HDDGS diets did, and all diets contained similar levels of CP. It is unclear what could have caused this response observed when feeding the HDDGS and MDDGS diets, but not the LDDGS diets. Crude fiber levels of diets containing DDGS could have contributed to decreases in carcass dressing percentage (Pond et al., 1988; Pond et al., 1999) since all DDGS diets contained higher CF levels than the control diet.

Last rib backfat thickness was decreased for pigs fed HDDGS diets compared to CON ($P < 0.05$), but not for the MDDGS or LDDGS treatments ($P > 0.10$). Many studies involving feeding diets containing DDGS have shown no difference in backfat thickness (Fu et al., 2004; Cook et al., 2005; Gaines et al., 2007b; Widmer et al., 2007). However, a reduction in backfat was observed by Whitney et al. (2006) and a linear effect of reduction in last rib backfat depth was reported by Xu et al. (2007), and these reductions are similar to what was observed in this study for pigs fed the HDDGS treatment. Measurements of 10^{th} rib backfat depth ($P = 0.48$) and loin muscle depth ($P = 0.18$) were not different among any of the dietary treatments. Carcass lean percentage also was not different among the dietary treatments.

SUMMARY

In conclusion, when feeding 20% DDGS originating from different ethanol plants to growing-finishing pigs, growth performance may be reduced when feeding sources with lower lysine digestibility, even when diets were formulated on a standardized ileal digestible amino acid basis using source specific digestibility values. However, feeding DDGS sources with moderate to high digestible lysine content can provide satisfactory growth performance. Water consumption appear to be unaffected by feeding diets containing DDGS. Feeding diets containing 20% DDGS may reduce carcass dressing percentage and last rib backfat depth, but other carcass characteristics appear to be unchanged regardless of DDGS source fed. When adding 20% DDGS to growing-finishing swine diets, variation in quality and nutrient content of DDGS sources should be considered in order to avoid reductions in growth performance.

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Table 1. Composition and nutrient analysis of the experimental phase 1 diets 50-80 kg (as-fed basis).

	Diet[1]			
Item	**CON**	**HDDGS**	**MDDGS**	**LDDGS**
Ingredient,%				
Corn	81.40	65.53	64.80	64.25
Soybean Meal (48% CP)	16.40	12.50	13.25	13.80
DDGS	0.00	20.00	20.00	20.00
Dicalcium Phosphate	0.75	0.14	0.11	0.11
Limestone	0.75	1.13	1.14	1.14
Vitamin/ trace mineral premix[2]	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30
L-Lys HCl	0.15	0.15	0.15	0.15
Analyzed composition				
ME, kcal/kg[3]	3,338	3,325	3,326	3,325
CP, %	14.4	17.5	17.3	17.2
Crude fat, %	2.92	4.16	4.44	4.34
Crude fiber, %	2.37	3.36	3.28	3.42
Lys, %	0.80	0.93	0.89	0.92
Met, %	0.20	0.32	0.27	0.28
Thr, %	0.46	0.62	0.61	0.58
Trp, %	0.16	0.18	0.18	0.18
SID Lys, %[4]	0.73	0.73	0.73	0.73
SID Trp, %[4]	0.14	0.14	0.13	0.13
SID Thr, %[4]	0.46	0.52	0.51	0.53
SID Met + Cys, %[4]	0.46	0.52	0.53	0.54
Ca, %	0.55	0.58	0.49	0.56
P, %	0.44	0.42	0.43	0.41
Salt, %	0.44	0.61	0.48	0.52
Avail. P, %[5]	0.19	0.19	0.19	0.19
Ca:Avail P[5]	2.89	3.05	2.58	2.95

[1] CON = control diet, HDDGS = high Lys digestible DDGS, MDDGS = medium Lys digestible DDGS and LDDGS = low Lys digestible DDGS

[2]Vitamin-trace mineral premix that supplied the following nutrients per kilogram of feed: 5512.5 IU of vitamin A as retinyl acetate; 1,378 IU of vitamin D_3; 27.6 IU of vitamin E as DL-α-tocopherol acetate; 2.2 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 5.0 mg of riboflavin; 27.6 mg of niacin; 16.5 mg of pantothenic acid as D-calcium pantothenate; 248.1 mg of choline as choline chloride; 0.03 μg of vitamin B_{12}; 1.10 mg of pyridoxine; 0.83 mg of folic acid; 0.55 mg of thiamine; 1.10 mg of biotin; 1.10 mg of iodine as ethylenediamine dihydroiodide; 0.15 mg of selenium as sodium selenite; 42.4 mg of zinc as zinc oxide; 25.5 mg of iron as ferrous sulfate; 2.7 mg of copper as copper sulfate; and 9.0 mg of manganese as manganese oxide.

[3] ME values were calculated with NRC (1998) for corn and SBM and 3308 kcal/kg for DDGS

[4]SID (standardized ileal digestible) calculated with Corn and SBM values from NRC (1998) and DDGS values from Urriola et al. (2007)

[5] Calculated with analyzed Ca and P and availability of P in DDGS from Whitney and Shurson (2001)

Table 2. Composition and nutrient analysis of the experimental phase 2 diets 80-120 kg (as-fed basis).

	Diet[1]			
Item	**CON**	**HDDGS**	**MDDGS**	**LDDGS**
Ingredient,%				
Corn	87.65	71.80	71.17	70.47
Soybean Meal (48% CP)	10.30	6.35	7.00	7.70
DDGS	0.00	20.00	20.00	20.00
Dicalcium Phosphate	0.63	0.02	0.00	0.00
Limestone	0.72	1.12	1.12	1.12
Vitamin/ trace mineral premix[2]	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30
L-Lys HCl	0.15	0.15	0.15	0.15
L-Trp	0.00	0.01	0.01	0.01
Analyzed composition				
ME, kcal/kg[3]	3,346	3,332	3,332	3,332
CP, %	11.9	14.1	13.7	14.1
Crude fat, %	3.03	4.55	4.66	4.80
Crude fiber, %	2.14	3.06	2.88	2.88
Lys, %	0.69	0.75	0.76	0.78
Met, %	0.17	0.25	0.24	0.28
Thr, %	0.38	0.50	0.48	0.52
Trp, %	0.14	0.15	0.16	0.16
SID Lys, %[4]	0.57	0.57	0.57	0.57
SID Trp, %[4]	0.11	0.11	0.11	0.11
SID Thr, %[4]	0.37	0.43	0.42	0.44
SID Met + Cys, %[4]	0.40	0.46	0.47	0.48
Ca, %	0.53	0.57	0.45	0.46
P, %	0.40	0.37	0.38	0.38
Salt, %	0.61	0.39	0.46	0.63
Avail. P, %[5]	0.17	0.16	0.17	0.17
Ca:Avail P[5]	3.12	3.56	2.65	2.71

[1] CON = control diet, HDDGS = high Lys digestible DDGS, MDDGS = medium Lys digestible DDGS and LDDGS = low Lys digestible DDGS

[2]Vitamin-trace mineral premix that supplied the following nutrients per kilogram of feed: 5512.5 IU of vitamin A as retinyl acetate; 1,378 IU of vitamin D_3; 27.6 IU of vitamin E as DL-α-tocopherol acetate; 2.2 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 5.0 mg of riboflavin; 27.6 mg of niacin; 16.5 mg of pantothenic acid as D-calcium pantothenate; 248.1 mg of choline as choline chloride; 0.03 µg of vitamin B_{12}; 1.10 mg of pyridoxine; 0.83 mg of folic acid; 0.55 mg of thiamine; 1.10 mg of biotin; 1.10 mg of iodine as ethylenediamine dihydroiodide; 0.15 mg of selenium as sodium selenite; 42.4 mg of zinc as zinc oxide; 25.5 mg of iron as ferrous sulfate; 2.7 mg of copper as copper sulfate; and 9.0 mg of manganese as manganese oxide.

[3] ME values were calculated with NRC (1998) for corn and SBM and 3308 kcal/kg for DDGS

[4]SID (standardized ileal digestible) calculated with Corn and SBM values from NRC (1998) and DDGS values from Urriola et al., (2007)

[5]Calculated with analyzed Ca and P and availability of P from Whitney and Shurson (2001)

Table 3. Analyzed nutrient composition of the DDGS sources used for experimental diets (as-fed basis).

	Dietary Treatment[1]		
Analyte, %	**HDDGS**	**MDDGS**	**LDDGS**
CP	29.5	28.6	27.6
Crude Fiber	7.03	6.37	6.3
ADF	11.94	9.78	8.65
NDF	25.08	22.19	20.8
Crude Fat	10.42	10.62	11.05
Ash	4.89	6.39	5.22
Ca	0.02	0.02	0.03
P	0.67	0.70	0.79
Salt	0.28	0.26	0.30
Sulfur	0.72	0.89	0.81
Lys	1.02	1.07	0.95
Met + Cys	1.08	1.09	1.19
Thr	1.04	1.04	1.07
Trp	0.20	0.23	0.23
SID Lys coefficient[2]	0.67	0.56	0.55
SID Met + Cys coefficient[2]	0.75	0.75	0.73
SID Thr coefficient[2]	0.76	0.64	0.72
SID Trp coefficient[2]	0.71	0.57	0.46
Digestible Lys[2]	0.68	0.60	0.52
Lys:CP	3.46	3.74	3.44

[1] DDGS sources used, HDDGS = high Lys digestible DDGS, MDDGS = medium Lys digestible DDGS and LDDGS = low Lys digestible DDGS

[2] SID (standardized ileal digestible) AA values from Urriola et al., (2007)

Table 4. Effects of dietary DDGS source and gender on overall growth performance and growth performance by phase (least square means).

		Diets (D)[1]				Gender (G)			*P*-Values		
Phase[c]		CON	HDDGS	MDDGS	LDDGS	Barrows	Gilts	Pooled SE	D	G	D×G
	No. of pigs	111	111	112	110	223	221				
	No. of pens	14	14	14	14	28	28				
I											
	ADG, kg	0.95	0.97	0.98	0.92	0.98	0.92	0.020	0.15	0.006	0.034
	ADFI, kg	2.58	2.52	2.55	2.42	2.65	2.39	0.038	0.03	<0.001	<0.001
	G:F	0.37	0.39	0.38	0.38	0.37	0.39	0.005	0.06	0.004	0.02
II											
	ADG, kg	1.03	0.99	0.98	0.99	1.05	0.95	0.015	0.10	<0.001	<0.001
	ADFI, kg	3.24	3.04	3.11	3.11	3.29	2.96	0.029	<0.001	<0.001	<0.001
	G:F	0.32	0.33	0.32	0.32	0.32	0.32	0.004	0.37	0.39	0.56
Overall											
	Initial BW, kg	62.3	63.0	63.1	62.6	62.6	62.8	0.218	0.057	0.922	0.028
	CV, %[2]	8.80	8.12	8.09	6.98	7.92	8.08	0.541	0.135	0.769	0.934
	Final BW, kg	116.7	115.8	115.6	115.1	118.2	113.4	0.497	0.146	<0.001	0.278
	CV, %[2]	8.40[a]	6.94[ab]	7.24[ab]	6.19[b]	6.99	7.40	0.562	0.062	0.530	0.932
	ADG, kg	1.00[a]	0.98[ab]	0.98[ab]	0.96[b]	1.02	0.94	0.009	0.053	<0.001	0.475
	ADFI, kg	2.98[a]	2.83[b]	2.90[ab]	2.84[b]	3.04	2.73	0.024	<0.001	<0.001	0.195
	G:F	0.34[a]	0.35[b]	0.34[ab]	0.34[ab]	0.34	0.34	0.002	0.03	0.03	0.74
	ADWD[3],L	5.77	6.69	6.28	6.94	6.31	6.53	0.372	0.268	0.720	0.029
	W:F[4], L/kg	1.93	2.37	2.19	2.47	2.08	2.39	0.126	0.094	0.174	0.022

[c]Phase effect (P = 0.002).

[1] CON = control diet, HDDGS = high Lys digestible DDGS, MDDGS = medium Lys digestible DDGS and LDDGS = low Lys digestible DDGS

[2]Within pen coefficient of variation, %

[3] Average daily water intake (disappearance)

[4] Water disappearance to feed intake ratio

[ab]Within a row, means without a common superscript letter differ (P < 0.05).

Table 5. Effects of dietary DDGS source and gender on carcass characteristics (least square means).

Item	Dietary Treatment (D)[1]				Gender (G)		Pooled SE	*P*-Values		
	CON	HDDGS	MDDGS	LDDGS	Barrows	Gilts		D	S	D x S
No. of pigs	102	107	100	103	206	206				
Slaughter wt, kg	126.1	124.6	125.1	124.6	126.3	123.8	0.580	0.19	<0.001	0.806
HCW[2], kg	95.2[a]	93.2[b]	93.5[b]	94.1[ab]	94.7	93.3	0.447	0.007	0.002	0.840
Dressing %	75.5[a]	74.9[b]	74.8[b]	75.4[a]	75.1	75.2	0.150	<0.001	0.249	0.811
Last rib backfat depth[3], mm	29.4[a]	27.7[b]	27.9[ab]	28.6[ab]	29.1	27.6	0.415	0.019	<0.001	0.369
10[th] rib backfat depth[3], mm	20.5	20.0	20.5	19.8	21.1	19.3	0.392	0.481	<0.001	0.755
Loin depth, mm	60.8	58.6	58.0	58.2	58.0	59.8	1.011	0.183	0.070	0.908
% Lean[4]	53.64	53.71	53.30	53.74	52.92	54.28	0.310	0.740	<0.001	0.810

[ab]Within a row, means without a common superscript letter differ ($P < 0.05$).

[1]CON = control diet, HDDGS = high Lys digestible DDGS, MDDGS = medium Lys digestible DDGS and LDDGS = low Lys digestible DDGS

[2]Hot carcass weight (HCW) adjusted to a skin on basis

[3]Adjusted to a skin on basis

[4]Calculated from {58.85 + [(-0.61 x 10th rib BF depth, mm) + (0.12 X loin depth, mm).