Final Report
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I. Project Title: Use of 20% DDGS and higher amounts of synthetic amino acids to replace soybean meal in grow-finish swine diets

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II. ABSTRACT

Currently, many grower-finisher swine diets containing distiller's dried grains with solubles (DDGS) have inclusion rates of 10%. With current record high feed ingredient prices, pork producers are looking for strategies to reduce feed costs. One strategy is to add DDGS at a higher dietary inclusion rate to replace some of the corn, inorganic phosphate, and soybean meal in grower-finisher swine diets and reduce diets costs. Further reductions feed cost may be possible by further reducing the amount of soybean meal in the diet with a 20% dietary DDGS inclusion rate when relatively high levels of synthetic amino acids are added. No studies have been published to evaluate the effects of removing increasing amounts of soybean meal by adding 20% DDGS and synthetic amino acids on growth performance and carcass quality. Therefore, the objective of this study was to evaluate growth performance and carcass quality of grow-finish pigs fed diets containing 20% DDGS and different levels of synthetic amino acids (AA). A total of 216 crossbred pigs (BW = 39.2 ± 0.19 kg) were blocked by initial BW and assigned to 24 pens (9 pigs/pen). Pens within block were assigned randomly to one of 4 dietary treatments in a 3-phase feeding program. Diets were formulated on a standardized ileal digestible AA basis according to NRC (1998). Control diets (CON) were corn and soybean meal (SBM) based and contained 0.15% L-lysine HCl (L-lys). Experimental diets included 20% DDGS with step-wise reduction of SBM and progressive inclusion of synthetic amino acids (AA) as follows: 1) Low AA: SBM was minimally reduced so that only Lys supplementation was required; 2) Medium AA: SBM was reduced to the level that required supplementation of Lys and Trp; 3) High AA: SBM was reduced to a level requiring the supplementation of Lys, Trp, and Thr. Pigs were weighed and feed disappearance was determined every other week and at the end of each phase. All pigs were harvested when average BW reached 114 ± 1.04 kg. Weight gain and feed intake were reduced for pigs fed High AA ($P < 0.05$), and pigs fed Med AA diets tended to have reduced ADG and ADFI ($P < 0.08$) compared to CON. There was no difference in ADG and ADFI between pigs fed CON and Low AA diets. Dietary treatments did not affect G:F. Final BW was lower for pigs fed High AA ($P < 0.05$), and tended to be lower for pigs fed there was a trend for lower final BW for pigs fed Med AA ($P = 0.09$) diets compared to those fed CON diets. There were no differences in dressing percentage, loin depth, backfat thickness, and carcass lean percentage among dietary treatments. These results suggest that replacing some SBM with 20% DDGS and supplementary Lys (> 0.15%) to grower-finisher diets can result in similar growth performance to typical corn and soybean meal diets. However, replacing greater amounts of SBM with 20% DDGS, L-lys (>.30%), and synthetic Thr and Trp

reduced ADG and ADFI without affecting carcass characteristics.

III. INTRODUCTION

Corn distiller's dried grains with solubles (DDGS) is a co-product of fuel ethanol production after starch has been removed by fermentation. The U.S. ethanol industry produced 14.6 million metric tons of DDGS is 2007 (RFA, 2008), a figure projected to increase further in the future. Diversion of corn to ethanol production has resulted in increased feed costs making the use of DDGS a necessary alternative ingredient for use in swine diets. Use of DDGS has been most common in growing-finishing phases of production at a dietary inclusion rate of 10%. The ability to maintain optimal growth performance using higher dietary DDGS inclusion rates can help mitigate the increasing feed costs.

It is important to know the nutrient content and digestibility of feed ingredients so that diets can be accurately formulated. A wide range of nutrient variability has been reported among DDGS samples from different ethanol plants as well as within the same plant (Cromwell et al. 1993, and Spiehs et al. 2002). When feeding higher levels of DDGS to swine, it is important to formulate diets on a digestible amino acid basis (Whitney et al. 2006) to achieve optimal growth performance and carcass composition due to the large variation in AA digestibility of DDGS from different sources (Stein et al. 2006).

Theoretically, diets containing 20% DDGS should provide similar growth performance compared to typical corn and SBM diets if the diets are formulated to contain identical and adequate levels of digestible nutrients. Therefore, we hypothesized that replacing a portion of SBM with 20% DDGS supplemented with the proper level of synthetic AA will result in identical growth performance to current standard diets for grow-finish piglets.

VI. OBJECTIVES

This study evaluated growth performance and carcass composition of growing-finishing pigs fed diets formulated to contain 20% DDGS and increasing amounts of supplemental synthetic amino acids to replace soybean meal.

V. PROCEDURES

Animals

The protocol for this study was approved by the University of Minnesota Institutional Animal Care and Use Committee. Pigs were housed in an environmentally controlled finishing facility at the West Central Research and Outreach Center in Morris, MN. All pens (1.6 x 4.5 m) had a slotted concrete floor, and each was equipped with one 4-hole stainless steel feeder and 2 nipple drinkers. A total of 216 barrows and gilts weighing 39.1±0.19 kg were blocked by weight in 6 blocks per treatment and assigned to one of 4 treatment diets in 24 pens (5 barrows and 4 gilts/pen). Pens within block were randomly assigned to one of four dietary treatments (6 pens per treatment). Pigs were fed the assigned diet in a three-phase grow-finish feeding program with targeted BW of 30-60 kg, 60-90 kg, and 90-120 kg for phases 1 through 3, respectively. Each pen remained on the same dietary treatment for the duration of the study, but switched phases within each treatment based on the mean body weight for an individual pen. Animals were switched to the diets of the next phase when average BW for each pen was within 2.25 kg of the target weight. Pigs were monitored daily for general health and were provided *ad libitum* access to feed and water.

Dietary Treatments

Diet composition and analyzed nutrient content of experimental diets of phases 1-3 are summarized in Tables 1-3 respectively. Diets within each phase were formulated to contain similar levels of ME, true ileal digestible Lys, vitamins, and trace minerals that met or exceeded those recommended by NRC (1998). Dietary digestible Lys concentrations were formulated to be 0.89%, 0.72% and 0.58% for phases 1-3, respectively. Amino acid ratios relative to lysine were maintained at those recommended by NRC (1998) with the exception of threonine (while NRC recommends thr:lys ratio to be 0.60, our diets were formulated with minimum ratios of 0.59, 0.61, and 0.63 for phases 1-3, respectively). The DDGS used in this study was obtained from a modern ethanol plant (Golden Grain Energy, Mason City, IA) and had an analyzed composition of 28.6% CP, 1.02% Lys 10.26% crude fat, 0.2% Ca, and 0.71% P. This source was chosen because it was previously used to determine standardized ileal amino acid digestibility (Table 4; Urriola et al., 2007), allowing us to use more precision when formulating experimental due to the large variations in amino acid digestibility among sources as reported by Stein et al. (2006) and Urriola et al. (2007). The ME value for DDGS used in this study was estimated to contain 3307 kcal/kg.

Dietary treatments were formulated by the addition of 20% DDGS and the removal of all or a portion of the SBM from the diet based on the needed synthetic AA to meet ratios relative to lysine. The control treatment (CON) consisted of standard corn-SBM diets with 0.15% synthetic lysine. Low AA diets were formulated by removing as much SBM as possible without necessitating the addition of synthetic AA other than Lys to the diet. In this case, Trp was at its minimum acceptable ratio relative to Lys. The Med AA diets were formulated by removing more SBM until reaching the minimum acceptable Thr:Lys ratio, which mandated the addition of both synthetic Lys and Trp to the diet. The High AA diets were similarly formulated by removing even more SBM and adding synthetic Lys, Trp, and Thr to meet acceptable ratios relative to Lysine. Although the High AA diets in phase 1 and 2 had the lowest content of SBM, it remained high enough that no synthetic Met + Cys were needed. The phase 3 diet of the High AA treatment had all of the soybean meal removed.

Diets were also formulated on an available phosphorus basis to utilize the high phosphorus content and availability in DDGS. Values used for available phosphorus content for corn, soybean meal, and monocalcium phosphate were those reported in NRC (1998). For DDGS, a phosphorus availability value of 90% was used based on results reported by Whitney and Shurson (2001). In addition, phytase was added to the diets to increase P availability, and the Ca: available P ratio was maintained at levels between 2:1 and 3:1. Because of the higher P availability in DDGS and the addition of phytase to the experimental diets, inorganic P addition was needed only in the control diet. However, the removal of monocalcium phosphate from the experimental diets required the addition of more limestone to maintain adequate Ca: available P ratios; total Ca to total P was maintained at a minimum of 1:1 as recommended by NRC (1998).

Feed samples from each manufactured batch were collected and frozen at -20 °C until laboratory analysis could be performed. Samples from each batch within each phase were pooled and a half was submitted for proximate and mineral analysis by AOAC procedures (Minnesota Valley Testing Laboratories, New Ulm, MN), and the other was submitted for AA analysis using HPLC procedures (Experiment Station Chemical Laboratory, University of Missouri-Columbia).

Measurements

Body weight and feed disappearance were recorded every 2 wks to determine ADG, ADFI, and G: F. Body weight coefficient of variation for individual pigs was calculated at the beginning and end of the study to determine if the variation in body weights changed within each pen. Of the 216 pigs used, 203 were shipped to harvest. Four pigs died during the study and 9 others were removed due to lameness or morbidity.

At the end of the study, all pigs were shipped to a large commercial abattoir and harvested the following day. Of the 203 pigs shipped, useable carcass data were obtained from 194 pigs. Hot carcass weight and last rib backfat depth after skin removal were measured by plant personnel. The last rib backfat values reported here are adjusted to a skin-on basis by adding 2.54 mm (NPPC 2000). Hot carcass weights were also adjusted to a skin-on basis and reported here as both a skin-off and a skin-on basis. Dressing percentage was calculated using the hot carcass weights adjusted to a skin-on basis. The percentage of carcass lean was determined by using the 10^{th} rib backfat depth and loin depth measured with the Fat-O-Meater automated probe (SFK Technology A/S, Herlev, Denmark) and using the following equation {58.85 +[(-0.61 x 10^{th} rib backfat depth, mm) + (0.12 x loin depth, mm)]; Whitney et al., 2006).

Statistical Analysis

Pig performance and carcass composition data were analyzed as a randomized complete block design using the Proc Mixed procedure of SAS 9.1 (SAS Inst. Inc., Cary, NC). Analysis of variance (ANOVA) was used for overall growth performance responses (ADG, ADFI, and G: F) and carcass characteristics with repeated measures in time. The unstructured (UN) option was used to fit a covariance structure in the model for final body weight. The pen was used as the experimental unit for all analyses. All statistical analysis included the dietary treatments as a fixed effect and the block as a random effect. All results are reported as least square means and multiple comparisons between treatments were performed using the Tukey-Kramer adjustment option. Treatment effects were considered significant at $P < 0.05$, whereas $P < 0.10$ was considered a statistically significant trend.

VI. RESULTS & DISCUSSION

Growth Performance

Feeding diets containing 20% DDGS to grow-finish pigs has led to inconsistent responses on pig growth performance. Some reports in the literature have shown similar performance (Wahlstrom et al., 1970; Cook et al., 2005; DeDecker et al., 2005; Widmer et al., 2007; Xu et al., 2007) while others have shown reduced performance (Fu et al., 2004; Widyarante et al., 2004; Whitney et al., 2006; Hinson et al., 2007; Linneen et al., 2007) when pigs were fed diets containing more than 10% DDGS compared to control diets. These inconsistent results could be due to variation in the DDGS quality, overestimation of amino acid digestibility in DDGS, diet formulation methods used, or excess crude protein (nitrogen), and other experimental factors.

Least square means for overall pig growth performance and their significance are shown in Table 5. For the duration of the trial, ADG and ADFI were not different between CON and Low AA diets ($P = 0.35$ and 0.13, respectively). Compared to CON, pigs fed High AA had significantly lower ADG ($P = 0.008$) and ADFI ($P < 0.04$), and those fed Med AA tended to be lower for ADG ($P < 0.08$) and ADFI ($P = 0.06$). There were no differences in overall G: F among any of the treatments. Final body weights were not different for pigs fed the CON and Low AA diets ($P = 0.30$), but those fed High AA were significantly lighter ($P = 0.007$). Pigs fed Med AA tended to have lower ($P = 0.09$) final body weights compared to CON. Within pen, the coefficient of variation of initial and final body weights did not differ ($P > 0.10$) for any of the dietary treatments. This indicates that there were no differences in the variation in final body weights within pen for any of the dietary treatments compared to the control. These results are similar to those reported previously by Whitney et al. (2006) that showed no difference in coefficient of variation of pigs fed 20% DDGS diets compared to the control diets.

Pig performance by different dietary phases is shown in Table 6. Growth performance was different in some phases, but not in others, which may help explain the differences observed for the overall growth performance. During Phase 1, there were no significant differences between dietary treatments for ADG ($P > 0.33$), ADFI ($P > 0.27$), and G: F ($P>0.28$). During phase 2, there were no effects of dietary treatments on ADFI and G:F, but ADG was affected by diets. While ADG for pigs fed CON, Low AA and High AA diets were not significantly different from each other, pigs fed Med AA tended to have lower ADG ($P < 0.06$) lower than CON. Pigs fed Low AA tended to have lower G: F ($P = 0.06$) compared to CON, but not a significantly lower ADFI ($P > 0.18$). Also in phase 2, pigs in the High AA group tended to have reduced ADG ($P = 0.06$) and did have reduced G: F ($P = 0.03$), but did not differ from CON in ADFI ($P = 0.71$). Some reductions in pig performance among dietary treatments were also observed during phase 3 (Table 6). Pigs fed the Low AA diets had reduced ADG ($P = 0.04$) and ADFI ($P = 0.01$) compared to CON, but showed no reduction in G: F ($P > 0.81$). Pigs fed Med AA had similar ADG ($P = 0.69$), ADFI ($P = 0.10$), and G: F ($P < 0.40$) to pigs fed CON.

Some studies have shown similar decreases in feed intake when feeding diets containing 20% DDGS or higher (Fu et al., 2004; Whitney et al., 2006), while others have not (Xu et al., 2007; DeDecker et al., 2005). These differences may be due to different formulation methods and estimates of digestible amino acids in the feed ingredients. High levels of synthetic lysine may also contribute to a reduction in growth performance. Supplementation levels of L-lysine HCl in phases 1, 2, and 3 were quite high at levels of 0.50%, 0.55%, and 0.43%, respectively in High AA diets. Ratliff et al. (2004) showed that L-Lysine HCl inclusion in excess of 0.50% in diets of nursery pigs may reduce ADG. Another concern for reducing the amount of SBM in the diet and using supplemental synthetic amino acids to meet the first 3 to 4 limiting essential amino acid requirements may result in inadequate levels of non-essential amino acids. Lenis et al. (1999) reported that reduced ratios of nonessential to essential amino acids in the diet may reduce growth performance. Kendall et al. (2004) also showed that certain levels of non-essential amino acids are required in corn-SBM diets containing high levels of L-Lysine HCL. This may have also occurred in Med AA and High AA diets fed in this study.

The reduction in ADG and ADFI by feeding some diets in some phases may have been caused by limiting amounts of other essential amino acids other than lysine. In some cases, as more SBM was removed from the diet, the levels of a few other essential amino acids were below NRC (1998) recommended minimum ratios relative to lysine. For example, the Med AA phase 2 diet had a digestible Val:Lys ratio of 63%, which was lower than the recommended 68%

in NRC (1998) and may have resulted in the reduction in ADG observed. Similarly, pigs fed High AA during phase 2 had reduced ADG compared to CON which may have been due to inadequate levels of digestible Val and His because the ratios relative to Lys were lower (42 and 25%, respectively) compared to those (68 and 32%, respectively) recommended by NRC (1998). Furthermore, pigs fed High AA in phase 3 had lower ADG and ADFI than CON which may have been due to below recommended digestible Val and His ratios (42 and 25%, respectively). However, the digestible Val and His ratios for Med AA in phase 1 (52 and 29%, respectively) and the digestible Val:Lys ratio in phase 3 was lower (60%) than recommended by NRC (1998) but no reductions in ADG and ADFI were observed relative to CON. Therefore, it is unclear whether the digestible Val and His ratios relative to digestible Lys in 20% DDGS diets with relatively low amounts of SBM are a significant factor that must be monitored when formulating diets with relatively high amounts of synthetic amino acids in order to avoid reductions in growth performance.

Carcass Composition

Carcass measurements are summarized in Table 7 and are presented as the least square means along with the P-values for treatment comparisons. Slaughter weights of pigs fed Low AA diets were not different from CON, but pigs fed High AA had lower ($P = 0.007$), and those fed Med AA tended to have ($P = 0.09$) lower final body weights than CON. The reduction in slaughter weights of pigs fed these dietary treatments was due to the overall reduction in ADG compared to CON. Skinned, hot carcass weights of High AA differed from CON ($P = 0.04$), but was not from the other treatments. Hot carcass weights adjusted to a skin-on basis was significantly ($P = 0.05$) reduced for High AA compared to CON, while the unadjusted hot carcass weights were not different among dietary treatments. Due to the reduction in slaughter weight of pigs fed the High AA diets, it would be expected that hot carcass weight would also be reduced. Carcass dressing percentage was similar ($P > 0.68$) among all dietary treatments, which agrees with results from studies where grower-finisher swine diets containing 20% DDGS were evaluated (Xu et al., 2008; Fu et al., 2004), but different from other reports showing decreased dressing percentage in pigs fed diets containing DDGS (Whitney et al., 2006; Xu et al., 2007; Cook et al., 2005; Feoli et al., 2007; Gaines et al., 2007). The observed reduction in dressing percentage of pigs fed DDGS diets reported by the groups cited above may have resulted from an increase in visceral weight because other carcass measurements are largely unchanged. No differences were observed in other carcass measurements including backfat depth ($P > 0.99$), percentage carcass lean ($P > 0.17$) and loin depth ($P > 0.95$) among any of the dietary treatments.

Results from this study show that including 20% distillers dried grain with solubles in conventional swine grower-finisher swine diets can result in acceptable growth performance and carcass quality when 0.20 to 0.22% L-lysine HCl is added and to replace a portion of the corn, SBM, and inorganic phosphate when diets are formulated on a standardized ileal digestible AA basis. However, excessive removal of SBM from the diet with increased supplementary synthetic amino acids resulted in decreased ADFI and ADG. It appears that the observed reduction in ADG and ADFI when feeding the Med AA and High AA diets may be due to deficiencies of other AA rather than lysine. Despite the reduction in ADG and ADFI observed when replacing increasing amounts of SBM with 20% DDGS and supplemental synthetic AA carcass composition appears to be unaffected.

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Table 1. Composition of the experimental phase 1 diets 30-60 kg (as-fed basis).

Item	CON	Low AA	Med AA	High AA
Ingredient,%				
Corn	72.04	57.46	60.21	66.56
Soybean Meal	25.97	20.69	17.83	11.13
DDGS	0.00	20.00	20.00	20.00
Monocalcium Phosphate	0.33	0.00	0.00	0.00
Limestone	0.93	1.08	1.10	1.14
Vitamin/Trace Mineral Premix[a]	0.23	0.23	0.23	0.23
Salt	0.30	0.30	0.30	0.30
L-Lysine	0.15	0.22	0.30	0.49
L-Threonine	0.00	0.00	0.00	0.08
L-Tryptophan	0.00	0.00	0.01	0.04
Phytase	0.05	0.02	0.02	0.03
Analyzed composition				
Dry matter, %	86.59	87.39	87.38	87.72
Crude protein, %	16.69	18.92	18.88	16.32
Lysine, %	1.00	1.10	1.16	1.07
Methionine, %	0.26	0.33	0.30	0.27
Threonine, %	0.59	0.75	0.66	0.64
Tryptophan, %	0.20	0.21	0.20	0.18
ME, kcal/kg[b]	3342	3326	3323	3314
Calcium, %	0.55	0.50	0.44	0.46
Phosphorus, %	0.40	0.40	0.37	0.37
SID Lysine, %[c]	0.89	0.89	0.89	0.89

[a]Vitamin-trace mineral premix that supplied the following nutrients per kilogram of feed for phase I: 7,938 IU of vitamin A as retinyl acetate; 1,488 IU of vitamin D_3; 30 IU of vitamin E as DL-α-tocopherol acetate; 4.0 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 6.0 mg of riboflavin; 34.7 mg of niacin; 19.8 mg of pantothenic acid as D-calcium pantothenate; 39.7 µg of vitamin B_{12}; 0.99 mg of iodine as ethylenediamine dihydroiodide; 0.27 mg of selenium as sodium selenite; 54.6 mg of zinc as zinc oxide; 32.7 mg of iron as ferrous sulfate; 3.27 mg of copper as copper sulfate; and 10.9 mg of manganese as manganese oxide.

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

[c]SID lysine calculated with DDGS values from Urriola (2006)

Table 2. Composition of the experimental phase 2 diets 60-90 kg (as-fed basis).

Item	CON	Low AA	Med AA	High AA
Ingredient,%				
Corn	79.75	64.52	67.81	75.87
Soybean Meal	18.65	13.95	10.52	2.02
DDGS	0.00	20.00	20.00	20.00
Monocalcium Phosphate	0.16	0.00	0.00	0.00
Limestone	0.76	0.84	0.86	0.91
Vitamin/Trace Mineral Premix[a]	0.18	0.18	0.18	0.18
Salt	0.30	0.30	0.30	0.30
L-Lysine	0.15	0.20	0.30	0.55
L-Threonine	0.00	0.00	0.00	0.10
L-Tryptophan	0.00	0.00	0.02	0.06
Phytase	0.05	0.01	0.01	0.01
Analyzed composition				
Dry matter, %	86.37	87.02	86.84	86.71
Crude protein, %	14.40	16.70	15.50	12.60
Lysine, %	0.82	0.92	0.88	0.89
Methionine, %	0.21	0.29	0.25	0.23
Threonine, %	0.49	0.62	0.52	0.53
Tryptophan, %	0.16	0.17	0.16	0.16
ME, kcal/kg[b]	3358	3340	3337	3325
Calcium, %	0.48	0.46	0.44	0.47
Phosphorus, %	0.34	0.38	0.38	0.43
SID Lysine, %[c]	0.72	0.72	0.72	0.72

[a]Vitamin-trace mineral premix that supplied the following nutrients per kilogram of feed for phase II: 6,174 IU of vitamin A as retinyl acetate; 1,158 IU of vitamin D_3; 23.2 IU of vitamin E as DL-α-tocopherol acetate; 3.1 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 4.6 mg of riboflavin; 27.0 mg of niacin; 15.4 mg of pantothenic acid as D-calcium pantothenate; 30.9 µg of vitamin B_{12}; 0.77 mg of iodine as ethylenediamine dihydroiodide; 0.21 mg of selenium as sodium selenite; 42.4 mg of zinc as zinc oxide; 25.5 mg of iron as ferrous sulfate; 2.6 mg of copper as copper sulfate; and 8.5 mg of manganese as manganese oxide.

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

[c]SID lysine calculated with DDGS values from Urriola (2006)

Table 3. Composition of the experimental phase 3 diets 90-120 kg (as-fed basis).

Item	CON	Low AA	Med AA	High AA
Ingredient,%				
Corn	86.01	70.30	74.01	78.28
Soybean Meal	12.62	8.37	4.50	0.00
DDGS	0.00	20.00	20.00	20.00
Monocalcium Phosphate	0.07	0.00	0.00	0.00
Limestone	0.67	0.71	0.73	0.76
Vitamin/Trace Mineral Premix	0.13	0.13	0.13	0.13
Salt	0.30	0.30	0.30	0.30
L-Lysine	0.15	0.19	0.30	0.43
L-Threonine	0.00	0.00	0.00	0.05
L-Tryptophan	0.00	0.00	0.02	0.04
Phytase	0.05	0.00	0.01	0.01
Analyzed composition				
Dry matter, %	86.13	86.78	86.81	87.05
Crude protein, %	12.10	14.60	13.71	11.90
Lysine, %	0.67	0.74	0.71	0.72
Methionine, %	0.19	0.24	0.24	0.21
Threonine, %	0.42	0.49	0.48	0.44
Tryptophan, %	0.14	0.14	0.14	0.14
ME, kcal/kg[b]	3368	3349	3346	3339
Calcium, %	0.36	0.35	0.35	0.35
Phosphorus, %	0.29	0.33	0.36	0.34
SID Lysine, %[c]	0.58	0.58	0.58	0.58

[a]Vitamin-trace mineral premix that supplied the following nutrients per kilogram of feed for phase III: 4,410 IU of vitamin A as retinyl acetate; 827 IU of vitamin D_3; 16.5 IU of vitamin E as DL-α-tocopherol acetate; 2.2 mg of vitamin K as menadione dimethylpyrimidinol bisulfite; 3.3 mg of riboflavin; 19.3 mg of niacin; 11.0 mg of pantothenic acid as D-calcium pantothenate; 22.1 μg of vitamin B_{12}; 0.55 mg of iodine as ethylenediamine dihydroiodide; 0.15 mg of selenium as sodium selenite; 30.3 mg of zinc as zinc oxide; 18.2 mg of iron as ferrous sulfate; 1.8 mg of copper as copper sulfate; and 6.1 mg of manganese as manganese oxide.

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

[c]SID lysine calculated with DDGS values from Urriola (2006)

Table 4. Total and standardized ileal digestible (SID) amino acid (AA) values of DDGS used in the study.

	AA[a] (as is)	
	Total AA	**SID AA**
Lysine,%	0.85	0.48
Methionine,%	0.50	0.40
Phenylalanine,%	1.27	1.00
Threonine,%	0.99	0.63
Tryptophan,%	0.22	0.12
Isoleucine,%	0.98	0.70
Arginine,%	1.19	0.92
Valine,%	1.30	0.92
Histidine,%	0.72	0.54
Leucine,%	3.02	2.51
Cysteine,%	0.48	0.34

[a]AA values and digestibility from Urriola (2006).

Table 5. Least squares means for overall BW, ADG, ADFI, and G:F responses to dietary treatments.

	Dietary Treatment					P-value		
Item	**CON**	**Low AA**	**Med AA**	**High AA**	**Pooled SE**	**Low AA vs. CON**	**Med AA vs. CON**	**High AA vs. CON**
No. of pigs	53	50	50	53				
No. of pens	6	6	6	6				
Initial BW, kg	39.2	39.1	39.4	39.2	0.114	0.93	0.93	0.99
Initial CV, %[1]	3.66	3.82	3.63	4.90	0.315	0.99	1.000	0.36
ADG, g	952	921	904	884[a]	0.008	0.35	0.07	0.008
ADFI, g	2859	2721	2696	2681[a]	0.025	0.13	0.06	0.04
G: F	0.33	0.34	0.34	0.33	0.003	0.83	0.98	0.96
Final BW, kg	117.3	114.6	113.6	111.6[a]	0.630	0.29	0.092	0.007
Final CV, %[1]	7.13	5.54	9.05	7.85	0.534	0.64	0.50	0.95
No. of days	82	82	82	82				

[1]Within pen coefficient of variation, %
[a]Means within a row differ from control ($P < 0.05$).

Table 6. Least squares means for BW, ADG, ADFI, and G:F responses to dietary treatments by phase.

	Dietary Treatment					P-value		
Item	CON	Low AA	Med AA	High AA	Pooled SE	Low AA vs. CON	Med AA vs. CON	High AA vs. CON
Phase I								
ADG, g	878	846	850	851	0.014	0.34	0.41	0.42
ADFI, g	2257	2132	2206	2263	0.044	0.27	0.65	0.96
G: F	0.389	0.398	0.386	0.376	0.005	0.45	0.80	0.28
Phase II								
ADG, g	976	971	880 [a]	896	0.017	0.91	0.03	0.06
ADFI, g	2713	2766	2588	2678	0.035	0.55	0.18	0.71
G: F	0.361	0.351	0.340	0.335 [a]	0.004	0.40	0.08	0.029
Phase III								
ADG, g	1017	940[a]	1003	904[a]	0.015	0.04	0.69	0.005
ADFI, g	3565	3317[a]	3410	3180[a]	0.036	0.01	0.10	0.0004
G: F	0.286	0.283	0.294	0.285	0.004	0.81	0.40	0.92

[a]Means within a row differ from control ($P < 0.05$).

Table 7. Least squares means for carcass measurement responses to dietary treatments.

Item	Diets				Pooled SE	P-Value		
	CON	Low AA	Med AA	High AA		Low AA vs. CON	Med AA vs. CON	High AA vs. CON
Hot carcass weight, kg[1]	83.16	81.49	80.33	79.74[a]	0.496	0.50	0.11	0.04
Adjusted HCW, kg[2]	86.69	84.98	83.85	83.18	0.524	0.52	0.14	0.05
Dressing %[3]	73.84	73.84	73.94	74.31	0.169	1.00	0.99	0.69
Last rib backfat depth, mm	25.55	25.31	25.55	25.55	0.038	0.99	0.99	0.99
10th rib backfat depth, mm	18.77	16.89	18.23	17.02	0.312	0.11	0.90	0.15
Loin depth, mm	54.42	54.14	53.60	54.21	0.713	0.99	0.96	0.99
% Lean[4]	53.94	55.06	54.18	54.98	0.208	0.17	0.97	0.22

[1] Skin-off HCW
[2] HCW adjusted to a skin on basis
[3] Calculated with Adj. HCW
[4] Calculated from {58.85 +[(-0.61 x 10th rib BF depth, mm) + (0.12 X loin depth, mm).
[a]Means within a row differ from control ($P < 0.05$).