

Effects of Adding Enzymes to Diets Containing High Levels of Dried Distillers Grains with Solubles on Growth Performance of Finishing Pigs¹

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Summary

A total of 1,032 pigs (BW = 101.5 lb) were used in a 90-d experiment to determine the effects of adding enzymes to diets containing high levels of dried distillers grains with solubles (DDGS) on growth performance and carcass characteristics of finishing pigs. Pigs were blocked by BW and randomly allotted to 1 of 7 dietary treatments with 6 pens per treatment. The control diet contained 30% DDGS. The remaining treatments were arranged in a 2 × 3 factorial design based on DDGS (45 or 60%) and enzyme inclusion (none, product A, or product B). Enzyme products were commercially available and designed for use in swine diets containing DDGS. Pigs allotted to the 60% DDGS treatment were fed 45% DDGS during the first 2 wk of the experiment to acclimate the pigs to DDGS. The 4 heaviest pigs from each pen were sold at d 78, and DDGS levels for all treatments were decreased to 20% until the end of the trial. Overall (d 0 to 90), enzyme supplementation did not affect ADG ($P > 0.24$), ADFI ($P > 0.30$), or F/G ($P > 0.52$). From d 0 to 78, regardless of enzyme treatment, ADG decreased (linear; $P < 0.05$) as DDGS increased because of a reduction (quadratic; $P < 0.04$) in ADFI. After topping and adding Paylean to the diets at d 78, ADFI tended to increase (linear; $P < 0.06$) in pigs previously fed 45 and 60% DDGS. However, the decrease in ADFI from d 0 to 78 still resulted in an overall reduction (linear; $P < 0.04$) with increasing DDGS. Increasing DDGS did not affect ($P > 0.17$) overall ADG, F/G, or final weight. There were no differences in carcass weight and yield ($P > 0.65$) or in backfat, loin depth, percentage lean, and fat-free lean index ($P > 0.38$) after adjusting to a common carcass weight. Increasing dietary DDGS increased (linear; $P < 0.01$) iodine value of belly fat (77.2, 83.7, and 87.3 g/100 g, respectively). This study indicates that up to 60% DDGS may be added to pig diets without negatively affecting growth performance or carcass traits compared to 30% DDGS when levels are reduced to 20% for 12 d before market; however, fat iodine values will be significantly increased. Neither commercially available enzyme product had any effect on pig growth performance.

Key words: enzyme, dried distillers grains with solubles

Introduction

Prices of major feed ingredients used in swine diets, such as corn, have risen tremendously in recent years. This has resulted in increased use of alternative feed ingredients

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like dried distillers grains with solubles (DDGS) to reduce diets costs. Studies have shown that up to 20% DDGS can be effectively used in nursery and grow-finish diets without decreasing performance. However, the continued increase in prices of major feed ingredients in the summer of 2008 and lower pig prices had producers opting to use higher levels of DDGS to further reduce diet costs.

Several factors limit the use of higher levels of DDGS in swine diets. Compared with corn, DDGS has a relatively high CP content but lower digestibility of lysine. This could mean that additional synthetic lysine and other amino acids are needed to achieve the ideal balance of amino acids when high levels of DDGS are used in the diets. Palatability appears to be negatively affected by higher levels of DDGS, as previous studies have shown reductions in feed intake with increasing DDGS level in pig diets. Carcass quality and value also diminish at high DDGS levels. Because DDGS contains high amounts of corn oil, which contains a high percentage of unsaturated fatty acids, pigs fed DDGS tend to have softer fat in their carcasses as measured by increased iodine value (IV).

High amounts of non-starch polysaccharides are also present in DDGS, which can affect its nutritional value. Use of added dietary enzymes is one approach that may aid in non-starch polysaccharide digestion and improve the utilization of fibrous materials in DDGS. In recent studies at Kansas State University (K-State), pigs fed DDGS-containing diets with enzyme supplementation did not show significant improvements in growth performance compared with pigs fed non-enzyme-supplemented diets. However, those studies used relatively low levels of DDGS (15 to 30%). This study was conducted to determine the effects of enzyme supplementation of diets containing high levels of DDGS on the growth performance and carcass characteristics of growing-finishing pigs.

Procedures

This study was approved by and conducted in accordance with the guidelines of the K-State Institutional Animal Care and Use Committee. The trial was conducted in a commercial research finishing barn in southwestern Minnesota. The barns were naturally ventilated and double curtain sided. Pens were 18 × 10 ft with completely slatted flooring and deep pits for manure storage. Each pen contained 1 self-feeder and a cup waterer. The barn was equipped with a robotic feeding system capable of providing and measuring feed amounts on an individual pen basis.

A total of 1,032 pigs (PIC 337 × C22, initially 101.5 lb) were blocked on the basis of BW and allotted to 1 of 7 dietary treatments with 6 pens per treatment. The control treatment was a corn-soybean meal-based diet containing 30% DDGS. The remaining treatments were arranged in a 2 × 3 factorial design based on the level of DDGS (45 or 60%) and enzyme inclusion (none, product A, or product B). Enzymes used were commercial enzymes designed for use in DDGS-containing diets. Diets were fed in 4 phases. During the first 2 wk of the experiment (Phase 1), the 60% DDGS treatments contained only 45% DDGS. Phase 1 was fed from approximately 100 to 128 lb BW. Phase 2 was fed from 128 to 185 lb BW, Phase 3 from 185 to 230 lb BW, and Phase 4 from 230 to 270 lb BW (Table 1). Pigs were weighed every 2 wk from d 0 to 90 to determine ADG. On d 78, 4 of the heaviest pigs from each pen were sold in accordance

with the normal marketing procedure of the farm and DDGS levels were decreased to 20% in all dietary treatments. This adjustment was done to help alleviate the decreased carcass yield impact when pigs are fed high levels of DDGS prior to market. Ractopamine HCL (Paylean; Elanco Animal Health, Greenfield, IN) was added in all dietary treatments from d 78 to 90. Average daily feed intake and F/G were calculated from the feed delivery data generated through the automated feeding system every weigh day.

Pigs were individually tattooed at the end of the trial and transported to JBS Swift and Company (Worthington, MN) for processing and carcass data collection. Standard carcass criteria of loin and backfat depth, HCW, percentage lean, and yield were collected. Fat-free lean index (FFLI) was determined with the following equation: $50.767 + (0.035 \times \text{HCW}) - (8.979 \times \text{backfat})$. Belly fat samples were collected in 18 randomly selected pigs (6 pigs per treatment) from each of the groups that received dietary treatments without enzyme to determine fat IV. Iodine value analyses were conducted at Barrow-Agee Laboratories, LLC (Memphis, TN) using the cyclohexane-acetic acid method.⁴

Statistical analysis was performed by analysis of variance with the MIXED procedure of SAS (SAS Institute, Inc., Cary, NC). Data were analyzed as randomized complete block design with pen as the experimental unit. Backfat, loin depth, percentage lean, and FFLI were adjusted to a common carcass weight. Linear and polynomial contrasts were used to determine the main effects of increasing DDGS. The main effects of enzyme addition and DDGS addition were determined using single degree of freedom contrast and estimate statements.

Results and Discussion

From d 0 to 78, regardless of enzyme treatment, ADG decreased (linear; $P < 0.05$) as DDGS increased because of a reduction (quadratic; $P < 0.04$) in ADFI (Table 2). The greatest reduction in ADFI occurred when DDGS was increased from 30 to 45%, and there was a modest reduction when DDGS was increased from 45 to 60%. There were no differences in weight between treatments before and after topping on d 78. After pens were topped and ractopamine HCl was added to the diets at d 78, ADFI tended to increase (linear; $P < 0.06$) in pigs previously fed 45 and 60% DDGS. The decrease in ADFI from d 0 to 78 resulted in an overall ADFI reduction (linear; $P < 0.04$) with increasing DDGS but did not affect ($P > 0.17$) overall ADG, F/G, or final weight. Pigs fed 30% DDGS had a numerically lower mortality rate than pigs fed the 45 and 60% DDGS, but the difference was not statistically significant. Numerically, the group that was fed 30% DDGS had the highest percentage of pigs sold at full value.

There were no differences in carcass weight and percentage yield ($P > 0.65$) regardless of enzyme treatment or DDGS level (Tables 3 and 4). Although previous research has shown a reduction in carcass yield when DDGS increased in the diets, the reduction of DDGS to 20% during the last 12 d in this study possibly eliminated the negative effect of high DDGS levels on carcass yield. After adjusting to a common carcass weight, there were no differences between treatments for backfat, loin depth, percentage lean, and FFLI ($P > 0.38$). Iodine value of belly fat increased (77.2, 83.7, and 87.3 g/100 g,

⁴ AOCS. 1998. Official methods and recommended practices of the AOCS. 5th ed. Am. Oil. Chem. Soc., Champaign, IL. Method Cd 1d-92.

respectively) with increasing dietary DDGS (linear; $P < 0.01$). Overall (d 0 to 90), enzyme supplementation did not affect ADG ($P > 0.24$), ADFI ($P > 0.30$), F/G ($P > 0.53$), or any of the carcass parameters measured ($P > 0.29$) (Table 4).

In this study, added dietary enzymes did not result in any improvements in pig growth performance or carcass characteristics. This is similar to the results of previous studies at K-State in which DDGS-containing diets were supplemented with enzymes. The previous studies had lower levels of DDGS, which might have been insufficient to detect a significant response to enzyme in terms of growth. In this study, however, added dietary enzymes did not improve growth or feed efficiency, even in diets containing 60% DDGS. It is possible that the products used in this study may not have the optimal balance of enzyme activities specific for the substrates present in the DDGS used in the experimental diets. Other factors can also affect the efficacy of the enzyme products, such as the amount of enzyme used, age of the animal, overall nutrient density of the diet, and particle size. All of these could have played a role in limiting or preventing a response to the enzyme from a growth performance standpoint.

Previous studies at K-State indicated that up to 30% DDGS can be added to nursery and grow-finish diets without affecting performance. In this study, reductions in ADFI and ADG were observed as DDGS was increased from 30 to 60% from d 0 to 78. However, no further reductions in ADG and ADFI occurred when DDGS levels were decreased to 20% in all treatments and ractopamine HCl was added to the diets after d 78. These results suggest that decreasing DDGS levels in the diets to 20% for at least 12 d prior to market can help alleviate the negative effects of high levels of DDGS on ADG and ADFI.

The linear increase in IV seen in this experiment was expected. Previous studies conducted at K-State and by other universities have consistently shown a positive correlation between dietary DDGS and IV. This is due to the higher amounts of corn oil, which is high in unsaturated fat (high IV), present in DDGS. Iodine value increased by 10.1 g/100 g in pigs fed 60% DDGS compared to those fed 30%. This is equivalent to a 3.4 g/100 g increase in IV for every 10% increase (from 30 to 60%) in DDGS.

In conclusion, up to 60% DDGS can replace corn in diets for growing-finishing pigs as an option to reduce feed costs. The addition of enzymes, however, had no significant impact on growth and did not improve feed efficiency in growing-finishing pigs. High DDGS levels may slightly inhibit growth, but if finishing spaces are available to accommodate pigs for several more days to meet target weights and as long as the potential savings are greater than the extra space costs, using high levels of DDGS in a grow-finish diet is highly feasible. This study indicates that up to 60% DDGS may be added to pig diets without negatively affecting growth or carcass yield compared to 30% DDGS when levels are reduced to 20% for 12 d before market. However, belly fat IV will be increased and may affect carcass value depending on the market in which the pigs are sold.

Table 1. Phase 1 diet composition (as-fed basis)¹

| Ingredient ² , % | Phase 1 | | | Phase 2 | | | Phase 3 | | | Phase 4 ³ | | |
|---|---------|-------|-------|---------|-------|-------|---------|-------|-------|----------------------|-------|-------|
| | 30% | 45% | 60% | 30% | 45% | 60% | 30% | 45% | 60% | 30% | 45% | 60% |
| | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS | DDGS |
| Corn | 46.23 | 29.50 | 29.50 | 49.03 | 32.43 | 17.61 | 52.14 | 37.66 | 22.85 | 60.10 | 60.10 | 60.10 |
| Soybean meal (46.5% CP) | 16.61 | 15.40 | 15.40 | 14.12 | 12.84 | 11.69 | 10.85 | 9.68 | 8.53 | 11.63 | 11.63 | 11.63 |
| Bakery product | 6.90 | 6.90 | 6.90 | 6.83 | 6.83 | 6.83 | 5.00 | 5.00 | 5.00 | 6.83 | 6.83 | 6.83 |
| Choice white grease | 0.24 | 1.19 | 1.19 | 0.00 | 0.95 | 1.80 | 0.00 | 0.74 | 1.59 | --- | --- | --- |
| Limestone | 0.91 | 1.07 | 1.07 | 0.91 | 1.07 | 1.21 | 1.10 | 1.06 | 1.21 | 0.82 | 0.82 | 0.82 |
| Salt | 0.21 | 0.16 | 0.16 | 0.21 | 0.17 | 0.13 | 0.28 | 0.20 | 0.16 | 0.24 | 0.24 | 0.24 |
| L-threonine | 0.03 | --- | --- | 0.01 | --- | --- | --- | --- | --- | 0.025 | 0.025 | 0.025 |
| Stafac | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | --- | --- | --- |
| L-lysine HCl | 0.61 | 0.61 | 0.61 | 0.56 | 0.57 | 0.58 | 0.50 | 0.51 | 0.51 | 0.27 | 0.27 | 0.27 |
| DDGS ⁴ | 28.10 | 45.00 | 45.00 | 28.17 | 45.00 | 60.00 | 30.00 | 45.00 | 60.00 | 20.00 | 20.00 | 20.00 |
| OptiPhos | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Vitamin-trace mineral premix | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Calculated analysis | | | | | | | | | | | | |
| Standardized ileal digestible amino acids | | | | | | | | | | | | |
| Lysine, % | 1.06 | 1.08 | 1.08 | 0.97 | 0.99 | 1.01 | 0.86 | 0.87 | 0.89 | 0.71 | 0.71 | 0.71 |
| Methionine:lysine ratio, % | 29 | 33 | 33 | 31 | 34 | 38 | 34 | 37 | 41 | 37 | 37 | 37 |
| Met & Cys:lysine ratio, % | 60 | 66 | 66 | 63 | 70 | 76 | 69 | 76 | 83 | 76 | 76 | 76 |
| Threonine:lysine ratio, % | 60 | 62 | 62 | 60 | 65 | 69 | 63 | 68 | 74 | 70 | 70 | 70 |
| Tryptophan:lysine ratio, % | 16 | 16 | 16 | 16 | 16 | 17 | 16 | 17 | 17 | 19 | 19 | 19 |
| Total lysine, % | 1.22 | 1.28 | 1.28 | 1.13 | 1.18 | 1.23 | 1.01 | 1.06 | 1.11 | 0.84 | 0.84 | 0.84 |
| CP, % | 20.1 | 22.7 | 22.7 | 19.1 | 21.7 | 24.0 | 18.2 | 20.5 | 22.8 | 16.7 | 16.7 | 16.7 |
| SID Lys:calorie ratio, g/Mcal ME | 3.14 | 3.16 | 3.16 | 2.89 | 2.91 | 2.92 | 2.55 | 2.57 | 2.59 | 2.10 | 2.10 | 2.10 |
| ME, kcal/lb | 1,533 | 1,551 | 1,551 | 1,529 | 1,547 | 1,563 | 1,524 | 1,541 | 1,557 | 1,535 | 1,535 | 1,535 |
| Ca, % | 0.43 | 0.49 | 0.49 | 0.42 | 0.48 | 0.53 | 0.48 | 0.47 | 0.52 | 0.38 | 0.38 | 0.38 |
| P, % | 0.46 | 0.53 | 0.53 | 0.45 | 0.52 | 0.57 | 0.45 | 0.50 | 0.56 | 0.41 | 0.41 | 0.41 |
| Available P, % | 0.30 | 0.38 | 0.38 | 0.30 | 0.38 | 0.46 | 0.30 | 0.38 | 0.45 | 0.25 | 0.25 | 0.25 |

¹ Phases 1, 2, 3, and 4 fed from approximately 100 to 128 lb BW, 128 to 185 lb BW, 185 to 230 lb BW, and 230 to 270 lb BW, respectively.² A commercial enzyme blend containing protease, amylase, β -glucanase, pectinase, cellulase, and phytase (Product A) or an experimental proprietary blend of enzymes selected to have maximum activity for the non-starch polysaccharides in DDGS (Product B) was added in diets containing 45 and 60% DDGS in place of corn.³ Ractopamine HCl (Paylean, Elanco Animal Health, Greenfield, IN) at 4.5 g/ton was added at the expense of corn.⁴ Diets in the 60% DDGS treatment contained only 45% DDGS during Phase 1 (d 0 to 14).

Table 2. Effects of enzyme supplementation in diets containing high levels of DDGS on growth performance and carcass characteristics of grow-finish pigs¹

| | Treatment | | | | | | | | SE | Probability, $P <$ |
|------------------------------|-----------|--|-----------|-----------|-----------|-----------|-----------|-----------|------|--------------------|
| | 30% DDGS | | 45% DDGS | | 60% DDGS | | | | | |
| | No enzyme | | No enzyme | Product A | Product B | No enzyme | Product A | Product B | | |
| Weight, lb | | | | | | | | | | |
| d 0 | 101.6 | | 101.6 | 101.7 | 101.2 | 101.5 | 101.4 | 101.3 | 2.8 | 1.00 |
| d 78 (before topping) | 249.8 | | 248.5 | 247.7 | 244.6 | 243.7 | 247.2 | 247.3 | 4.2 | 0.95 |
| d 78 (after topping) | 244.5 | | 243.3 | 242.7 | 238.1 | 238.9 | 241.5 | 241.9 | 4.3 | 0.94 |
| Tops ² | 274.8 | | 272.9 | 272.2 | 277.0 | 267.5 | 274.9 | 272.5 | 5.0 | 0.81 |
| d 90 ³ | 270.9 | | 270.4 | 270.8 | 265.3 | 266.9 | 269.6 | 269.7 | 4.4 | 0.96 |
| d 0 to 78 ⁴ | | | | | | | | | | |
| ADG, lb | 1.89 | | 1.84 | 1.85 | 1.81 | 1.79 | 1.84 | 1.83 | 0.03 | 0.33 |
| ADFI, lb | 5.12 | | 4.91 | 4.90 | 4.76 | 4.78 | 4.94 | 4.83 | 0.07 | 0.03 |
| F/G | 2.71 | | 2.66 | 2.65 | 2.64 | 2.66 | 2.68 | 2.65 | 0.03 | 0.70 |
| d 78 to 90 ^{3,5} | | | | | | | | | | |
| ADG, lb | 2.15 | | 2.22 | 2.29 | 2.24 | 2.30 | 2.30 | 2.26 | 0.08 | 0.83 |
| ADFI, lb | 6.11 | | 6.61 | 6.70 | 6.40 | 6.51 | 6.63 | 6.57 | 0.21 | 0.47 |
| F/G | 2.86 | | 3.00 | 2.93 | 2.86 | 2.82 | 2.87 | 2.92 | 0.10 | 0.83 |
| d 0 to 90 ^{3,5} | | | | | | | | | | |
| ADG, lb | 1.92 | | 1.88 | 1.90 | 1.86 | 1.85 | 1.89 | 1.87 | 0.03 | 0.64 |
| ADFI, lb | 5.24 | | 5.10 | 5.11 | 4.95 | 4.98 | 5.13 | 5.03 | 0.08 | 0.18 |
| F/G | 2.73 | | 2.71 | 2.68 | 2.68 | 2.69 | 2.71 | 2.68 | 0.03 | 0.88 |
| Pigs removed and marketed, % | | | | | | | | | | |
| Mortality ⁶ | 2.07 | | 4.13 | 3.33 | 3.65 | 2.14 | 2.79 | 4.18 | 1.71 | 0.95 |
| Marginal value ⁷ | 0.95 | | 3.08 | 2.21 | 2.70 | 3.62 | 1.10 | 2.12 | 1.52 | 0.81 |
| Full value ⁸ | 97.05 | | 92.94 | 94.92 | 93.07 | 94.08 | 96.35 | 93.75 | 2.00 | 0.63 |

continued

Table 2. Effects of enzyme supplementation in diets containing high levels of DDGS on growth performance and carcass characteristics of grow-finish pigs¹

| | Treatment | | | | | | | | | |
|------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | 30% DDGS | | | 45% DDGS | | | 60% DDGS | | | |
| | No enzyme | No enzyme | Product A | Product B | No enzyme | Product A | Product B | No enzyme | Product A | Product B |
| | | | | | | | | | | |
| Carcass characteristics | | | | | | | | | | |
| Slaughter wt, lb | 266.8 | 266.1 | 266.6 | 261.5 | 263.3 | 264.0 | 264.9 | 4.1 | 0.97 | |
| Carcass wt, lb | 201.5 | 199.1 | 200.3 | 198.8 | 197.8 | 198.8 | 198.8 | 3.3 | 0.99 | |
| Yield, % | 75.6 | 75.0 | 75.5 | 75.6 | 75.2 | 75.5 | 74.9 | 0.4 | 0.65 | |
| Backfat, in. ⁹ | 0.67 | 0.67 | 0.67 | 0.68 | 0.68 | 0.70 | 0.65 | 0.01 | 0.44 | |
| Loin depth, in. ⁹ | 2.42 | 2.44 | 2.44 | 2.45 | 2.42 | 2.40 | 2.45 | 0.03 | 0.93 | |
| Lean, % ⁹ | 55.42 | 55.90 | 55.92 | 55.85 | 55.70 | 55.36 | 56.25 | 0.31 | 0.40 | |
| FFLJ ^{9,10} | 50.22 | 50.28 | 50.30 | 50.23 | 50.17 | 49.96 | 50.54 | 0.17 | 0.43 | |

¹ A total of 1,032 pigs (PIC 337 × C22), initially 101.5 lb, were used with 24 pigs per pen and 6 replications per treatment.² Removed after weighing on d 78.³ Only pigs that were on test up to d 90 (excluding tops) were included in the data analysis.⁴ All pigs that were on test up to d 78 (including tops) were used in the data analysis.⁵ Paylean was added to all dietary treatments from d 78 to 90, and all diets contained 20% DDGS during this 12-d period.⁶ Includes pigs that died, were culled, and were pulled off test during the experiment.⁷ Lightweight pigs sold at the end of the experiment.⁸ Top pigs and pigs that were sold at the end of the experiment excluding lightweight pigs.⁹ Data analyzed using carcass weight as a covariate.¹⁰ Fat-free lean index.

Table 3. Effects of diets containing high levels of DDGS on growth performance and carcass characteristics of grow-finish pigs¹

| | DDGS, % | | | | Probability, <i>P</i> < | | | |
|------------------------------|---------|-------|-------|------|-------------------------|-----------|-----------|--------|
| | 30 | 45 | 60 | SE | 30 vs. 45 | 30 vs. 60 | 45 vs. 60 | Linear |
| Weight, lb | | | | | | | | Quad |
| d 0 | 101.6 | 101.5 | 101.4 | 1.6 | 0.98 | 0.95 | 0.97 | 0.95 |
| d 78 (before topping) | 249.8 | 247.0 | 246.1 | 2.4 | 0.55 | 0.43 | 0.79 | 0.43 |
| d 78 (after topping) | 244.5 | 241.3 | 240.7 | 2.5 | 0.53 | 0.46 | 0.87 | 0.46 |
| Top ² | 274.8 | 274.0 | 271.6 | 3.0 | 0.89 | 0.55 | 0.50 | 0.55 |
| d 90 ³ | 270.9 | 268.8 | 268.7 | 2.5 | 0.69 | 0.68 | 0.98 | 0.68 |
| d 0 to 78 ⁴ | | | | | | | | |
| ADG, lb | 1.89 | 1.84 | 1.82 | 0.02 | 0.14 | 0.05 | 0.47 | 0.05 |
| ADFI, lb | 5.12 | 4.86 | 4.85 | 0.04 | 0.004 | 0.003 | 0.87 | 0.003 |
| F/G | 2.71 | 2.65 | 2.66 | 0.02 | 0.11 | 0.18 | 0.65 | 0.18 |
| d 78 to 90 ^{3,5} | | | | | | | | |
| ADG, lb | 2.15 | 2.25 | 2.29 | 0.05 | 0.30 | 0.15 | 0.57 | 0.15 |
| ADFI, lb | 6.11 | 6.57 | 6.57 | 0.12 | 0.06 | 0.06 | 0.99 | 0.06 |
| F/G | 2.86 | 2.93 | 2.87 | 0.06 | 0.54 | 0.94 | 0.41 | 0.94 |
| d 0 to 90 ^{4,6} | | | | | | | | |
| ADG, lb | 1.92 | 1.88 | 1.87 | 0.02 | 0.31 | 0.17 | 0.62 | 0.17 |
| ADFI, lb | 5.24 | 5.05 | 5.05 | 0.05 | 0.05 | 0.04 | 0.92 | 0.04 |
| F/G | 2.73 | 2.69 | 2.69 | 0.02 | 0.28 | 0.31 | 0.91 | 0.31 |
| Pigs removed and marketed, % | | | | | | | | |
| Mortality ⁶ | 2.07 | 3.70 | 3.04 | 0.99 | 0.41 | 0.62 | 0.63 | 0.62 |
| Marginal value ⁷ | 0.95 | 2.66 | 2.28 | 0.90 | 0.33 | 0.43 | 0.74 | 0.43 |
| Full value ⁸ | 97.05 | 93.64 | 94.73 | 1.17 | 0.14 | 0.29 | 0.47 | 0.29 |

continued

Table 3. Effects of diets containing high levels of DDGS on growth performance and carcass characteristics of grow-finish pigs¹

| Carcass characteristics | DDGS, % | | | SE | Probability, <i>P</i> < | | | |
|---|---------|-------|-------|------|-------------------------|-----------|-----------|--------|
| | 30 | 45 | 60 | | 30 vs. 45 | 30 vs. 60 | 45 vs. 60 | Linear |
| Slaughter wt, lb | 266.8 | 264.7 | 264.1 | 2.5 | 0.67 | 0.57 | 0.85 | 0.57 |
| Carcass wt, lb | 201.5 | 199.4 | 198.5 | 2.0 | 0.58 | 0.42 | 0.72 | 0.42 |
| Yield, % | 75.6 | 75.4 | 75.2 | 0.2 | 0.63 | 0.37 | 0.55 | 0.37 |
| Backfat, in | 0.67 | 0.67 | 0.68 | 0.01 | 0.95 | 0.83 | 0.71 | 0.83 |
| Loin depth, in | 2.42 | 2.44 | 2.42 | 0.02 | 0.57 | 0.97 | 0.46 | 0.97 |
| Lean, % | 55.42 | 55.9 | 55.8 | 0.2 | 0.20 | 0.33 | 0.65 | 0.33 |
| FFLI ⁹ | 50.22 | 50.3 | 50.2 | 0.1 | 0.81 | 0.98 | 0.76 | 0.98 |
| Belly fat iodine value, g/100 g ¹⁰ | 77.2 | 83.7 | 87.3 | 1.8 | --- | --- | --- | 0.002 |
| Quad | | | | | | | | 0.54 |

¹ A total of 1,032 pigs (PIC 337 × C22), initially 101.5 lb, were used with 24 pigs per pen and 6 replications per treatment.² Removed after weighing on d 78.³ Only pigs that were on test up to d 90 (excluding tops) were included in the data analysis.⁴ All pigs that were on test up to d 78 (including tops) were used in the data analysis.⁵ Paylean was added to all dietary treatments from d 78 to 90, and all diets contained 20% DDGS during this 12-d period.⁶ Includes pigs that died, were culled, and were pulled off test during the experiment.⁷ Lightweight pigs sold at the end of the experiment.⁸ Top pigs and pigs that were sold at the end of the experiment excluding lightweight pigs.⁹ Fat-free lean index.¹⁰ Values are means of 6 observations per treatment taken from each level of the non-enzyme-supplemented DDGS treatment.

Table 4. Effects of enzyme supplementation on growth performance and carcass characteristics of grow-finish pigs (main effects)¹

| | Enzyme ² | | | SE | Probability, <i>P</i> < | | |
|------------------------------|---------------------|-----------|-----------|------|-------------------------|------------------|------------------|
| | No | Product A | Product B | | No vs. Enzyme | No vs. Product A | No vs. Product B |
| Weight, lb | | | | | | | |
| d 0 | 101.5 | 101.5 | 101.2 | 2.0 | 0.94 | 1.00 | 0.91 |
| d 78 (before topping) | 246.1 | 247.4 | 246.0 | 3.0 | 0.87 | 0.75 | 0.97 |
| d 78 (after topping) | 241.1 | 242.1 | 240.0 | 3.0 | 0.99 | 0.82 | 0.80 |
| Top ³ | 270.2 | 273.5 | 274.7 | 3.7 | 0.29 | 0.45 | 0.31 |
| d 90 ⁴ | 268.6 | 270.2 | 267.5 | 3.1 | 0.95 | 0.72 | 0.81 |
| d 0 to 78 ⁵ | | | | | | | |
| ADG, lb | 1.82 | 1.85 | 1.82 | 0.02 | 0.48 | 0.28 | 0.93 |
| ADFI, lb | 4.85 | 4.92 | 4.80 | 0.05 | 0.84 | 0.30 | 0.49 |
| F/G | 2.66 | 2.66 | 2.64 | 0.02 | 0.73 | 0.98 | 0.53 |
| d 78 to 90 ^{4,6} | | | | | | | |
| ADG, lb | 2.26 | 2.30 | 2.25 | 0.06 | 0.83 | 0.64 | 0.92 |
| ADFI, lb | 6.56 | 6.67 | 6.48 | 0.15 | 0.95 | 0.60 | 0.68 |
| F/G | 2.91 | 2.90 | 2.89 | 0.07 | 0.80 | 0.88 | 0.77 |
| d 0 to 90 ^{4,6} | | | | | | | |
| ADG, lb | 1.87 | 1.90 | 1.87 | 0.02 | 0.45 | 0.24 | 0.92 |
| ADFI, lb | 5.04 | 5.12 | 4.99 | 0.06 | 0.84 | 0.30 | 0.49 |
| F/G | 2.70 | 2.69 | 2.68 | 0.02 | 0.69 | 0.95 | 0.53 |
| Pigs removed and marketed, % | | | | | | | |
| Mortality ⁷ | 3.14 | 3.06 | 3.92 | 1.22 | 0.81 | 0.96 | 0.65 |
| Marginal value ⁸ | 3.35 | 1.65 | 2.41 | 1.11 | 0.27 | 0.23 | 0.51 |
| Full value ⁹ | 93.51 | 95.64 | 93.41 | 1.45 | 0.52 | 0.25 | 0.96 |
| Carcass characteristics | | | | | | | |
| Slaughter wt, lb | 264.7 | 265.3 | 263.2 | 3.2 | 0.91 | 0.89 | 0.73 |
| Carcass wt, lb | 198.5 | 199.5 | 198.8 | 2.5 | 0.80 | 0.74 | 0.92 |
| Yield, % | 75.1 | 75.5 | 75.3 | 0.3 | 0.41 | 0.29 | 0.70 |
| Backfat, in. | 0.68 | 0.69 | 0.66 | 0.01 | 0.79 | 0.60 | 0.33 |
| Loin depth, in. | 2.43 | 2.42 | 2.44 | 0.02 | 0.92 | 0.74 | 0.61 |
| Lean, % | 55.8 | 55.6 | 56.1 | 0.2 | 0.88 | 0.62 | 0.45 |
| FFLI ¹⁰ | 50.2 | 50.1 | 50.4 | 0.1 | 0.84 | 0.59 | 0.38 |

¹ A total of 1,032 pigs (PIC 337 × C22), initially 101.5 lb, were used with 24 pigs per pen and 6 replications per treatment.

² No = means of 45% DDGS and 60% DDGS treatments without enzyme; A = means of 45% DDGS + Product A and 60% DDGS + Product A; B = means of 45% DDGS + Product B and 60% DDGS + Product B.

³ Removed after weighing on d 78.

⁴ Only pigs that were on test up to d 90 (excluding tops) were included in the data analysis.

⁵ All pigs that were on test up to d 78 (including tops) were used in the data analysis.

⁶ Paylean was added to all dietary treatments from d 78 to 90, and all diets contained 20% DDGS during this 12-d period.

⁷ Includes pigs that died, were culled, and were pulled off test during the experiment.

⁸ Lightweight pigs sold at the end of the experiment.

⁹ Top pigs and pigs that were sold at the end of the experiment excluding lightweight pigs.

¹⁰ Fat-free lean index.