Title: Critical evaluation of commercially available enzymes, and processing on nutrient digestibility of swine diets containing DDGS **- NPB #08-111**

Investigator: Brian J. Kerr, Ph.D.

Institution: USDA-ARS-NLAE, Ames, IA

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Industry Summary:
Application of enzymes in an effort to improve nutrient digestibility of plant-based feed ingredients for swine and poultry has been studied for decades. Essentially, an enzyme(s) must match the target substrate(s) in a feedstuff which have been shown to have a negative impact on nutrient digestibility or voluntary feed intake. As such, there may need to be a 'cocktail' of enzymes to effectively breakdown the complex matrixes of fibrous carbohydrate structures. With the inverse relationship between fiber content and energy digestibility being well described for several feed ingredients, it is only logical that development of enzymes that degrade fiber, and thereby improve energy digestibility or voluntary feed intake, will have a chance to be beneficial, both metabolically and economically. The current experiment involved the evaluation of 10 commercially available feed additives (enzymes, yeast, and probiotics) in nursery and finisher pigs fed diets containing 30% DDGS, each over a 5 week period. Efficacy was based upon apparent total tract nutrient digestibility (as measured indirectly using dietary markers) and pig performance. Overall, the results of the current experiment suggest that commercially available enzyme/additive products have variable (both positive and/or negative) effects on nutrient digestibility coefficients, but none of these products were effective in improving starter or finishing pig growth performance when fed nutritionally adequate corn-soy diets containing 30% DDGS. For further information, contact Dr. Brian Kerr, USDA-ARS-NLAE, Ames, IA, by phone (515-294-0224) or email (brian.kerr@ars.usda.gov).

Keywords: dried distillers grains with solubles, enzymes, nutrient digestibility

Scientific Abstract
Ten commercially available feed additives were selected based on their potential to affect energy and fiber digestion, or their ability to modulate gastrointestinal bacterial ecology. A total of 192 nursery pigs (11.9 kg initial BW) and 96 finishing pigs 48 pigs (98.4 kg initial BW) were allotted to individual pens and fed their respective diet for 5-wk. Diets contained corn, soybean meal, and 30% dried distillers grains with solubles

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For more information contact:
National Pork Board • PO Box 9114 • Des Moines, IA 50306 USA • 800-456-7675 • Fax: 515-223-2646 • pork.org

(DDGS), were adequate in all nutrients (NRC, 1998) and were offered ad libitum in meal form. Additives were added at the recommended rates and were assumed to contain the active ingredients and activity level listed on the product label. Titanium dioxide was added as an indigestible marker to determine apparent total tract DM, C, N, S, P, EE, ADF, and NDF digestibility at the end of wk 1, 3, and 5. Data were analyzed using ANOVA with group, room, gender, week, and diet included in the model. In nursery pigs, digestibility of most nutrients were unaffected by additives. Roxazyme tended to improve N and S digestibility ($P \leq 0.1$) and Rovabio and BactoCell tended to improve ($P \leq 0.06$) S digestibility. Porzyme and Hemicell tended to decrease ($P \leq 0.09$) NDF digestibility and XVC yeast tended to reduce P digestibility ($P \leq 0.1$). Econase, Allzyme, and Rele-e-zyme decreased digestibility of various nutrients. For finisher pigs, all additives had minimal effects on digestibility of most nutrients. Roxazyme tended to improve ($P \leq 0.08$) EE, Hemicel tended to decrease NDF and ADF digestibility ($P \leq 0.08$), Allzyme tended to increase NDF, ADF and P digestibility ($P \leq 0.08$), Bactocel tended to decrease N digestibility ($P \leq 0.05$), XVC yeast reduced N and C digestibility ($P \leq 0.1$), and Bioplus2B tended to improve ADF digestibility ($P \leq 0.1$), but decrease P and EE digestibility ($P \leq 0.04$). Addition of Porzyme and Rel-e-ezyme caused negative effects on digestibility of various nutrients. Additives had no effect ($P > 0.1$) on starter or finishing pig performance. In conclusion, addition of these commercial additives to corn-soybean meal-30% DDGS diets appear to have minimal effects on nutrient digestibility in nursery and finishing pigs, and do not improve growth performance.

Introduction:
Plant carbohydrates can be classified into three categories: 1) simple sugars and their conjugates (glucose, fructose, etc.); 2) storage reserve compounds (starch); and 3) structural carbohydrates (cellulose, hemicellulose, etc.). Simple sugars and storage compounds are primarily digested in the upper gastrointestinal tract, although not completely, while structural carbohydrates are only partially degraded by the microflora in the cecum and large intestine (Slominski, 1991). The hindgut volatile fatty acid (VFA) production in the pig has been estimated to contribute between 5 and 28% of the total maintenance energy requirement (Friend et al., 1964; Imoto and Namioka, 1978). Because most of the starch is removed from corn during ethanol production, the resultant by-product, dried distillers grains with solubles (DDGS), contains concentrated levels of protein, minerals, and fiber (≈ 25% NDF; Spiehs et al., 2002; Pedersen et al., 2007). With pigs being able to utilize moderate, but not high levels of fiber in the nursery (Whitney and Shurson, 2004; Weber et al., 2007) and finishing (Whitney et al., 2006) period, there is a need to increase the ability of the pig to utilize the energy contained in structural carbohydrates contained in corn-derived co-products (Muley et al., 2007).

The addition of exogenous enzymes in efforts to improve nutrient digestion is not a new concept and has been reviewed in detail (Chesson, 1987; Bedford, 2000). However, the majority of commercial enzyme products have been targeted toward poultry (Annison and Choct, 1991; Cowan, 1993) and are typically added to diets containing barley, oats, peas, rye, or wheat (Aimonen and Nasi, 1991; Thacker et al., 1992; Viveros et al., 1994; Huberner et al., 2002), although some studies have evaluated their use in corn-soybean meal diets (Saleh et al., 2005). In pigs, a multi-enzyme preparation added to diets containing various cereal grains and fed to 6 kg pigs improved growth performance and various nutrient indices (Omogbenigun et al., 2004). Likewise, adding a multi-enzyme complex to diets containing barley and wheat improved the digestibility of soluble non-starch polysaccharides in 10 kg pigs, although growth performance was not affected (Inborr et al., 1993). Adding xylanase to diets containing wheat by-products and fed to 15 kg pigs improved overall and ileal apparent digestibility of dry matter, crude protein, and energy, especially in diets containing high levels of dietary fiber (Yin et al., 2000). One of the few published studies in growing/finishing pigs fed corn-soy diets found an increase in growth performance in pigs supplemented with beta-mannanase, but minimal effects on nutrient digestibility were observed (Pettey et al., 2002). Lastly, adding an enzyme cocktail to a diet containing soy hulls improved dry matter and energy digestibility in 33 kg pigs (Moeser and van Kempen, 2002). More recently, it has been reported that adding an enzyme preparation to diets containing 30% DDGS increased growth performance in nursery pigs (Spencer et al., 2007). Whether dietary enzyme additions will enhance growth performance in finishing pigs fed diets containing increased levels of corn fiber remains unreported.

Unfortunately, the results of studies where there was no effect of dietary enzymes on pig growth performance are largely unreported in the scientific literature, which has led to a paucity of peer-reviewed data available to pork producers, swine nutritionists, and other pork industry professionals. However, the variation in responses noted with enzyme addition in pig diets has been reported by Nonn et al. (1999), who found no effect of enzyme supplementation on pig growth performance, but increased digestibility of crude fiber and cellulose. In addition, Thacker and Campbell (1999) also indicated that although enzyme supplementation increased nutrient digestibility coefficients, there was little effect on pig growth performance.

Objectives of Research Project:
Objectives of the proposed research were to evaluate the ability of commercially available enzyme, yeast, or probiotic preparations to improve the apparent dry matter (DM), lipid (EE), phosphorus (P), nitrogen (N), sulfur (S), phosphorus (P), energy (E), and fiber (NDF and ADF) digestibility of diets containing 30% corn dried distillers grains with solubles (DDGS) fed to nursery or finisher pigs, each over a 5 wk period.

Materials & Methods
The experiment was approved by the Iowa State University Animal Care and Use Committee. Feed additives (Table 1) were selected based on their potential to affect energy and fiber digestion, or their ability to modulate the bacterial ecology within the gastrointestinal tract. The basal diets (Table 2) were formulated to be adequate in all nutrients relative to the NRC (1998) recommendation for each specific pig weight category over the 5 wk period, and included 30% DDGS during each phase of growth. Titanium dioxide was added as an indigestible marker at 0.5% of the diet to determine apparent "nutrient" digestibility by the indirect method: $[1 – ((Ti_{feed} \times Nutrient_{feces})/(Ti_{feces} \times Nutrient_{feed})) \times 100]$. Feed additives were added at the manufacturers recommended rates to each diet. For all additives evaluated in this study, it was assumed that they contained the active ingredients and the level of activity listed on the product label (Table 1).

In the nursery experiment, a total of 192 pigs were used representing 3 groups of 64 pigs (11.9 kg average initial BW). Each group of pigs were randomly allotted to 2 rooms (32 pens/room) and subsequently placed into individual stainless steel pens measuring 0.46 m × 1.22 m. Pigs were individually fed their respective experimental diets over a 5 week feeding period. In the finisher experiment, a total of 96 pigs were used consisting of 2 groups of 48 pigs (98.4 kg average initial BW), which were randomly allotted to 2 rooms (24 pens/room), and subsequently placed into individual galvanized pens measuring 0.57 × 2.21 m. Pigs were individually fed their experimental diets over the 5 week feeding period. In each experiment, pigs were allowed *ad libitum* access to feed and water, and each room was maintained with 24-h lighting, was mechanically ventilated, and had a pull-plug manure storage system. Dietary treatments were randomly assigned to pens, with gender and BW maintained as equal as possible within and between groups. Experimental diets were fed in meal form. Fecal samples were collected at the end of wk-1, wk -3, and wk -5 by collecting freshly voided feces into individual plastic bags and immediately storing samples at 0˚C until the end of the trial.

At the end of the trial, diets and feces were dried in a 70˚C forced air oven, weighed, ground through a 1-mm screen, and a subsample was obtained for nutrient analysis. Diet and fecal samples were analyzed in duplicate. Carbon, N, and S were analyzed using thermocombustion (VarioMax, Elementar Analysensysteme GmbH, Hanau, Germany). Acid and neutral detergent fiber was analyzed by method # 8 and #9, respectively, using filter-bag technology (Ankom2000, Ankom Technology, Macedon, NY). Ether extract was analyzed using petroleum ether as described by Luthria et al. (2004) using an ASE 350 (Dionex Corporation, Sunnyvale, CA). Gross energy was determined using an isoperibol bomb calorimeter (Model 1281, Parr Instrument Co., Moline, IL), with benzoic acid used as a standard. Phosphorus was digested with concentrated nitric acid following method (II)A (AMC, 1960) in 1N HCl followed by ICP spectrometry (Optima 5300DV, PerkinElmer, Shelton, CT).

Data were subjected to ANOVA (Proc GLM, SAS Inst. Inc., Cary, NC) with group, room, gender, week, and diet included in the model. There were no week × diet interactions, therefore, only the main effects of diet and week are presented, with means are reported as LSMEANS. In addition, only the pre-planned comparison between pigs fed each feed additive and pigs fed the diet containing no additive are presented. The pig was considered the experimental unit in each experiment.

RESULTS

STARTER: In the starter experiment, most nutrient digestibility coefficients were unaffected by the addition of enzymes, yeast, or microbial cultures (Table 3). Nitrogen and S digestibility were improved by Roxazyme addition, but the digestibility of other nutrients was unaffected. In a similar manner, Rovabio and BactoCel both improved S digestibility, but the digestibility of all other nutrients was unaffected by their addition. It is unclear what, if any, value of an improved S digestibility may provide in these diets. In contrast, Porzyme and Hemicel decreased NDF digestibility, but did not affect other nutrient digestibility coefficients. This was an unexpected result since the product labels for these additives indicated the presence of enzymes that should be effective for improving digestibility of corn fiber. It was also expected that the addition of XVC yeast decreased P digestibility. Supplementation of Econase, Allzyme, and Releezyme decreased the digestibility of various nutrients. However, regardless of positive or negative impact that enzymes, yeast, or microbial cultures had on the digestibility of various nutrients, there was no impact on pig performance (Table 5). Digestibility of GE, N, C, S, P, ADF, NDF and ether extract all increased from wk-1 to wk-5 ($P < 0.01$). These results suggest that the gastrointestinal tract of the 12 kg pig adapts to dietary fiber from DDGS and nutrient digestibility improves with continuous feeding over time. This finding is consistent with the increased ability of the digestive system in growing pigs to digest nutrients (especially fiber) with increasing age.

FINISHER: In the finisher experiment, little impact of enzymes, yeast, or microbial cultures were noted on most nutrient digestibility coefficients (Table 4). Improvements in digestibilities were noted for the addition of Roxazyme (EE), Allzyme (P, ADF, and NDF), and BioPlus2B (ADF), but the digestibilities of all other nutrients were unaffected. However, the improvement in fiber digestibility from adding Allzyme and BioPlus2B did not result in improved gross energy digestibility. Supplementation of Porzyme, Hemicel, Releezyme, XPC yeast and BactoCel exhibited negative impacts on digestibility of various nutrients. Regardless of these impacts (negative and/or positive) on nutrient digestibility, there was no impact of enzymes, yeast, or microbial cultures on pig performance (Table 5). In contrast to the improvement in nutrient digestibility responses observed for starter pigs over time, nutrient digestibility did not improve from wk-1 to wk-5 in finishing pigs.

DISCUSSION

Many of the enzyme/additive products evaluated in this study contained ingredients that should have been effective in for improving energy/fiber digestibility in 30% DDGS diets. Since we did not confirm the specified enzyme/active ingredient activity for these additives, it may be possible that they did not contain enough activity to provide significant improvements in digestibility for many of the nutrients evaluated. Another possible reason for the lack of growth performance and notable nutrient digestibility responses may have been due to the source of DDGS included in the diet. Urriola et al. (2010) showed that apparent total tract digestibility of dietary fiber can range from 23 to 55% among DDGS sources. Perhaps the DDGS source used in this study was low in digestible fiber, and therefore, the ability of the products evaluated to affect nutrient digestibility could not be achieved. Finally, since these diets were formulated to meet the nutrient needs of pigs in each growth phase evaluated, the improvements or decreases in nutrient digestibility that did occur were too small to influence overall pig performance. In conclusion, addition of these commercial additives to corn-soybean meal-30% DDGS diets appear to have minimal effects on nutrient digestibility in nursery and finishing pigs, and do not improve growth performance.

Table 1. Characterization of exogenous feed additives				
Trade name	Manufacture	Lot # Date	Activity identification	Stated Activity
Allzyme SSF	Alltech, Lexington, KY	215612/460369 2/2/2008	Not provided (NP)	NP
Bactocell	Lallemand Animal Nutrition, Milwaukee, WI	8022202 3/3/2008	Pediococcus acidilactici	10×10^{9} CFU/g
BioPlus 2B	Chr. Hansen, Milwaukee, WI	2821721 1/31/2008	Bacillus licheniformis and Bacillus subtilus	2.2×10^{9} CFU/g
Econase XT25	AB Enzymes, Darmstadt, Germany	7855 12/19/2007	Endo-1,4-β-xylanase	160,000 U/g
Hemicel	ChemGen Corp., Gaithersburg, MD	NP NP	Hemicellulase	1.4×10^{6} U/g
Porzyme 9302	Danisco Animal Nutrition, Marlborough, UK	4320849505 8/11/2008	Xylanase	8,000 U/g
Releez-a-zyme 4M	Prince Agri Products Inc., Quincy, IL	31-2047 5/6/2008	β-glucanase Protease	440 U/g 11 U/g
Rovabio AP10%	Adisseo, Antony, France	NP NP	Endo-1,4-β-xylanase Endo-1,3(4)- β-glucanase	2,200 U/g 200 U/g
Roxazyme G2 G	DSM Nutritional Products Inc., Parsippany, NJ	NP NP	Endo-1,4-β-glucanase Endo-1,3(4)- β-glucanase Endo-1,4-β-xylanase	8,000 U/g 18,000 U/g 26,000 U/g
XPC yeast	Diamond V Mills Inc., Cedar Rapids, IA	300308 NP	*Saccharomyces cerevisiae* yeast culture	NP

Table 2. Composition of experimental diets, as-is basis		
Ingredient	Starter	Finisher
Corn	41.69	61.98
Soybean meal	16.94	4.85
Dried distillers grains with solubles	30.00	30.00
Whey, dried	5.00	-
Fish meal	2.50	-
Soybean oil	0.52	-
Dicalcium phosphate (21%P)	0.34	-
Limestone	0.96	1.11
Sodium chloride	0.35	0.35
Vitamin mix[1]	0.30	0.25
Trace mineral mix[2]	0.11	0.10
L-lysine·HCl	0.27	0.33
L-tryptophan	0.02	0.03
Dehulled, degermed corn	0.45	0.475
Antibiotic[3]	0.05	0.025
Titanium dioxide	0.50	0.50
TOTAL	100.00	100.00

[1]Provided the following per kilogram of starter and finisher diet, respectively: vitamin A, 6,614/5,512 IU; vitamin D_3, 1,653/1,378 IU; vitamin E, 33/28 IU; vitamin B_{12}, 0.033/0.028 mg; riboflavin, 10/8 mg; niacin, 50/41 mg; pantothenic acid, 26/22 mg.
[2]Provided the following per kilogram of starter and finisher diet, respectively: Cu (oxide), 11/9 mg; Fe (sulfate), 105/88 mg; I (CaI), 1.2/1.0 mg; Mn (oxide) 36/30 mg; Zn (oxide), 90/75 mg; Se (Na_2SeO_3), 0.3 mg.
[3]Tylosin premix.

Table 3. Apparent total tract digestibility (%) of starter pigs fed exogenous feed additives[1]

Treatment[2]	GE	N	C	S	P	ADF	NDF	EE
Control	79.2	79.9	79.9	78.5	60.1	40.1	36.6	64.2
Roxazyme	79.6	81.1	80.3	79.9	59.1	38.8	39.1	63.3
P value[3]	*0.40*	*0.10*	*0.42*	*0.06*	*0.38*	*0.58*	*0.16*	*0.61*
Porzyme	79.0	79.4	79.7	78.8	58.4	36.3	33.2	64.9
P value[3]	*0.67*	*0.47*	*0.61*	*0.66*	*0.16*	*0.13*	*0.07*	*0.67*
Econase	78.3	78.7	79.1	77.0	54.0	35.6	32.5	62.8
P value[3]	*0.07*	*0.07*	*0.10*	*0.04*	*0.01*	*0.06*	*0.03*	*0.45*
Rovabio	80.0	80.7	80.7	79.9	59.5	38.1	36.5	64.4
P value[3]	*0.12*	*0.25*	*0.14*	*0.06*	*0.61*	*0.39*	*0.97*	*0.88*
Hemicel	78.9	79.0	79.6	79.0	59.5	36.3	33.4	65.5
P value[3]	*0.53*	*0.17*	*0.48*	*0.49*	*0.60*	*0.12*	*0.09*	*0.45*
Allzyme	76.5	77.6	77.4	77.5	55.6	30.6	27.3	61.5
P value[3]	*0.01*	*0.01*	*0.01*	*0.17*	*0.01*	*0.01*	*0.01*	*0.14*
Releezyme	76.9	77.4	77.7	77.3	56.1	30.0	29.9	61.1
P value[3]	*0.01*	*0.01*	*0.01*	*0.09*	*0.01*	*0.01*	*0.01*	*0.08*
XVC yeast	79.6	80.1	80.3	79.4	57.9	39.0	36.4	65.9
P value[3]	*0.40*	*0.81*	*0.46*	*0.26*	*0.06*	*0.63*	*0.95*	*0.33*
BactoCel	80.0	80.4	80.3	80.1	59.8	39.4	39.3	64.9
P value[3]	*0.14*	*0.55*	*0.42*	*0.03*	*0.79*	*0.76*	*0.15*	*0.66*
BioPlus2B	79.5	80.3	80.0	79.6	58.7	37.7	35.0	65.0
P value[3]	*0.59*	*0.64*	*0.85*	*0.17*	*0.24*	*0.31*	*0.39*	*0.64*
P value[4]	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.08*
SE[4]	0.35	0.48	0.34	0.52	0.80	1.714	1.318	1.221
Wk-1[5]	76.9	76.0	77.6	75.4	55.3	31.4	28.5	70.6
Wk-3	79.2	80.1	79.8	79.3	58.9	36.2	35.8	61.9
Wk-5	80.5	82.4	81.2	81.8	60.0	42.0	39.1	59.4
P value[6]	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
SE[6]	0.18	0.25	0.18	0.27	0.42	0.93	0.69	0.64

[1] Apparent digestibility calculated using indirect marker methodology. There were 16 to 18 individually fed pigs per dietary treatment.

[2] Roxazyme G2, 200 g/T (DSM Nutritional Products Inc., Parsippany, NJ); Porzyme 9302, 227 g/T (Danisco Animal Nutrition, Marlborough, UK); Econase XT25, 136 g/T (AB Enzymes, Darmstadt, Germany); Rovabio AP10, 454 g/T (Adisseo, Antony, France); Hemicel, 454 g/T (ChemGen Corp., Gaithersburg, MD); Allzyme SSF, 454 g/T (Alltech, Lexington, KY); Release, 454 g/T (Prince Agri Products Inc., Quincy, IL); XPC Yeast, 1,816 g/T (Diamond V Mills Inc., Cedar Rapids, IA); BactoCel, 100 g/T (Lallemand Animal Nutrition, Milwaukee, WI); BioPlus 2B, 454 g/t (Chr. Hansen, Milwaukee, WI).

[3] 'P value' represents comparison of the feed additive to the control diet.

[4] Model P and SE value for overall diet effect.

[5] Initial, wk-1, wk-3, and wk-5 BW of 11.88, 13.96, 23.23, and 33.26 kg, respectively.

[6] Model P and SE value for week.

Table 4. Apparent total tract digestibility (%) of finisher pigs fed exogenous feed additives[1]								
Treatment[2]	GE	N	C	S	P	ADF	NDF	EE
Control	81.4	83.8	82.3	82.7	37.2	52.9	42.1	46.5
Roxazyme	80.9	81.9	81.7	81.9	40.2	49.8	38.1	49.9
P value[3]	*0.45*	*0.12*	*0.35*	*0.27*	*0.22*	*0.15*	*0.14*	*0.08*
Porzyme	79.4	80.9	80.4	80.1	29.3	43.8	34.0	44.4
P value[3]	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.28*
Econase	80.8	82.7	81.8	83.1	34.8	50.8	42.0	46.7
P value[3]	*0.40*	*0.15*	*0.45*	*0.55*	*0.34*	*0.33*	*0.95*	*0.82*
Rovabio	81.3	83.7	82.3	82.8	33.8	52.7	43.5	45.5
P value[3]	*0.98*	*0.92*	*0.96*	*0.88*	*0.18*	*0.93*	*0.62*	*0.62*
Hemicel	80.7	82.8	81.6	82.4	36.6	48.3	37.4	44.3
P value[3]	*0.30*	*0.20*	*0.27*	*0.74*	*0.83*	*0.03*	*0.08*	*0.25*
Allzyme	82.1	84.2	83.00	83.3	42.2	56.6	46.9	48.1
P value[3]	*0.27*	*0.61*	*0.29*	*0.38*	*0.04*	*0.08*	*0.08*	*0.41*
Releezyme	79.5	80.7	80.4	79.9	38.5	50.0	35.4	38.1
P value[3]	*0.01*	*0.01*	*0.01*	*0.01*	*0.59*	*0.18*	*0.02*	*0.01*
XVC yeast	80.1	82.5	81.1	82.1	38.1	50.1	38.4	43.1
P value[3]	*0.05*	*0.10*	*0.05*	*0.36*	*0.71*	*0.19*	*0.18*	*0.08*
BactoCel	80.8	82.3	82.0	82.4	39.7	50.1	39.5	49.6
P value[3]	*0.40*	*0.05*	*0.57*	*0.73*	*0.29*	*0.19*	*0.34*	*0.11*
BioPlus2B	81.7	83.2	82.7	82.6	31.9	56.3	45.4	38.6
P value[3]	*0.58*	*0.46*	*0.49*	*0.91*	*0.04*	*0.10*	*0.23*	*0.01*
P value[4]	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
SE[4]	0.45	0.55	0.45	0.47	1.79	1.50	1.95	1.38
Wk-1[5]	80.6	82.3	81.5	81.7	35.3	50.7	40.1	45.3
Wk-3	80.8	82.5	81.8	82.3	36.6	51.7	40.5	44.9
Wk-5	81.0	83.0	82.0	82.3	37.8	50.8	40.2	44.8
P value[6]	*0.43*	*0.17*	*0.39*	*0.17*	*0.14*	*0.62*	*0.96*	*0.89*
SE[6]	0.24	0.30	0.24	0.25	0.99	0.80	1.04	0.73

[1] Apparent digestibility calculated using indirect marker methodology. There were 8 individually fed pigs per dietary treatment (P digestibility represents 4 pigs per dietary treatment).

[2] Roxazyme G2, 200 g/T (DSM Nutritional Products Inc., Parsippany, NJ); Porzyme 9302, 227 g/T (Danisco Animal Nutrition, Marlborough, UK); Econase XT25, 136 g/T (AB Enzymes, Darmstadt, Germany); Rovabio AP10, 454 g/T (Adisseo, Antony, France); Hemicel, 454 g/T (ChemGen Corp., Gaithersburg, MD); Allzyme SSF, 454 g/T (Alltech, Lexington, KY); Release, 454 g/T (Prince Agri Products Inc., Quincy, IL); XPC Yeast, 908 g/T (Diamond V Mills Inc., Cedar Rapids, IA); BactoCel, 100 g/T (Lallemand Animal Nutrition, Milwaukee, WI); BioPlus 2B, 454 g/t (Chr. Hansen, Milwaukee, WI).

[3] 'P value' represents comparison of the feed additive to the control diet.

[4] Model P and SE value for overall diet effect.

[5] Initial, wk-1, wk-3, and wk-5 BW of 98.40, 104.90, 119.52, and 132.20 kg, respectively.

[6] Model P and SE value for week.

Table 5. Performance of pigs fed exogenous feed additives[1]

Treatment[2]	Starter, 12 – 33 kg BW ADG, kg	ADFI, kg	G:F	Finisher, 98 – 132 kg BW ADG, kg	ADFI, kg	G:F
Control	0.640	1.126	0.572	0.999	3.032	0.333
Roxazyme	0.638	1.100	0.583	0.975	3.084	0.321
Porzyme	0.642	1.131	0.570	0.979	3.077	0.318
Econase	0.653	1.133	0.578	1.051	3.240	0.325
Rovabio	0.648	1.148	0.565	0.906	2.985	0.302
Hemicel	0.629	1.149	0.551	0.933	3.239	0.292
Allzyme	0.651	1.140	0.574	0.961	3.118	0.311
Releezyme	0.639	1.109	0.579	0.983	3.115	0.311
XVC yeast	0.653	1.157	0.568	0.862	2.930	0.294
BactoCel	0.615	1.083	0.568	1.007	3.084	0.328
BioPlus2B	0.645	1.162	0.559	0.988	3.179	0.315
P value	*0.87*	*0.70*	*0.72*	*0.60*	*0.90*	*0.56*
SE	0.016	0.030	0.011	0.057	0.141	0.014

[1] Performance over the 5-wk period. There were 16-18 and 8 individually fed pigs per treatment in the starter and finisher phase, respectively.

[2] Roxazyme G2, 200 g/T (DSM Nutritional Products Inc., Parsippany, NJ); Porzyme 9302, 227 g/T (Danisco Animal Nutrition, Marlborough, UK); Econase XT25, 136 g/T (AB Enzymes, Darmstadt, Germany); Rovabio AP10, 454 g/T (Adisseo, Antony, France); Hemicel, 454 g/T (ChemGen Corp., Gaithersburg, MD); Allzyme SSF, 454 g/T (Alltech, Lexington, KY); Release, 454 g/T (Prince Agri Products Inc., Quincy, IL); XVC Yeast, 1,816 g/T starter or 908 g/T finisher (Diamond V Mills Inc., Cedar Rapids, IA); BactoCel, 100 g/T (Lallemand Animal Nutrition, Milwaukee, WI); BioPlus 2B, 454 g/t (Chr. Hansen, Milwaukee, WI).