NON-STARCH POLYSACCHARIDES ENZYME SUPPLEMENTATION OF GROWING-FINISHING PIG DIETS WITH REDUCED METABOLIZABLE ENERGY AND DIGESTIBLE AMINO ACIDS

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ABSTRACT

The study evaluated the effects of supplementing non-starch polysaccharides enzyme (NSPE) to a corn-soybean meal based diet with reduced ME and digestible amino acids (DAA) on growth performance, carcass characteristics, and economic return in growing-finishing pigs. A total of 54 barrows (Duroc-Pietrain × Landrace-Large White) with an initial BW of 25.6±1.6 kg were randomly assigned using a completely randomized design to 3 dietary treatments: positive control (PC, formulated under local industry nutrient specifications), negative control (NC, reduced to 65 kcal ME/kg and 1.5% DAA) and NC + NSPE. The NSPE is a commercial preparation (Rovabio Excel AP, Adisseo France) produced from fermentation of non-genetically modified *Penicilium funiculosum*. The NSPE was added at the rate of 50 g/100 kg of the diet. Each treatment had 6 replicate pens with 3 pigs per pen. Pigs fed the diet with NSPE had improved (*P*<0.05) ADG and F:G compared with those fed the PC and NC diets in the starter phase, and tended (*P*<0.08) to have improved F:G and final weights in the overall phase. There was no indication that the reduction in ME and DAA compromised performance of the pigs. Dietary effects on carcass characteristics were not observed. The inclusion of NSPE to the diet with reduced ME and DAA decreased (*P*<0.03) cost per kg gain during the starter, grower, and overall phase. In conclusion, results indicate that the NSPE can be used satisfactorily in growing-finishing pig diets with reduced ME and DAA.

Keywords: Pigs, non-starch polysaccharides, metabolizable energy, digestible amino acids, enzymes

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INTRODUCTION

Diets for growing-finishing pigs in the Philippines are largely corn-soybean meal based formulations. Agricultural co-products of vegetable origin such as rice bran, copra meal and corn dried distillers grains with solubles (DDGS) are, likewise, used in diets to reduce feed cost. However, these co-products contain high levels of non-starch polysaccharides (NSP), which are poorly digested by enzymes in the small intestine but are completely or partially fermented by microbes (De Vries, 2004). The NSP in diets are nutritionally significant in two accounts: firstly, they are large potential dietary energy sources that are unutilized and, secondly, they are anti-nutritional compounds acting in various mechanisms with consequent adverse effects on biological and economic efficiency of pig production.

Pigs are inherently devoid of endogenous enzymes needed for effective degradation of NSP (Pluske and Lindemann, 1997). As such, dietary supplementation of exogenous enzymes is one area of research aimed at mitigating the problems related to NSP (Choct, 2006). A commercial NSP-degrading enzyme with 5 major groups of enzymes (xylanase, β-glucanase, cellulases, pectinases and proteases), with ancillary enzyme activities for each enzyme groups, was the subject of the present study. Recent studies of supplementing this NSPE increased nutrient digestibility and daily gain in growing pigs (Cozannet *et al*., 2012; Fang *et al.*, 2007) and increased dietary energy intake in sows which was reflected in terms of improved growth of piglets (Walsh *et al*., 2012). However, there is limited data on the use of the NSPE in diets fed under local conditions. Therefore, the study was conducted to assess effects of supplementing NSPE to a diet with reduced ME and DAA on growth performance, carcass characteristics and diet economics in growing-finishing pigs.

MATERIALS AND METHODS

Animals and Treatments

A total of 54 growing barrows (Duroc-Pietrain x Landrace-Large White) with an initial BW of 25.6±1.6 kg and 70 d of age were used in the study. Pigs were randomly assigned to 3 experimental treatments using a completely randomized design. Each treatment had 6 replications with 3 pigs per replicate pen.

The experimental treatments were 1) Positive control (PC, formulated to meet local industry nutrients specifications), 2) Negative control (NC, reduced ME by 65 kcal/kg and DAA by 1.5%), and 3) NC supplemented with NSPE (NC + NSPE). All the diets were corn-soybean meal based diets with rice bran D1, copra meal, and corn DDGS. Dietary treatments were fed in 3 phases (Tables 1, 2, and 3).

Table 1. Ingredient and nutrient composition (as-fed basis) of experimental diets fed during the starter phase (d 0 to 30)

Item	Price/kg (PhP)	Positive Control (PC)	Negative Control (NC)	NC + NSPE
Ingredient, %				
Yellow corn	14.80	55.88	58.31	58.31
Soybean meal, US	35.00	21.70	20.90	20.90
Rice bran D1	11.50	7.00	7.00	7.00
Copra meal	9.50	5.00	5.00	5.00
DDGS, corn	22.00	2.26	1.84	1.84
Molasses	18.00	2.00	2.00	2.00
Coconut oil	46.00	2.33	1.11	1.11
Monodicalcium phosphate	35.00	1.16	1.18	1.18
Limestone	1.60	1.24	1.24	1.23
L-lysine	115.00	0.44	0.45	0.45
L-threonine	160.00	0.20	0.20	0.20
DL-methionine	210.00	0.16	0.15	0.15
L-tryptophan	1,200.00	0.04	0.04	0.04
Salt	6.00	0.38	0.38	0.38
Vitamin premix[1]	1,150.00	0.03	0.03	0.03
Mineral premix[2]	102.00	0.06	0.06	0.06
Toxin binder	320.00	0.05	0.05	0.05
Copper sulfate	128.00	0.05	0.05	0.05
Ethoxyquin	250.00	0.02	0.02	0.02
NSP enzyme (NSPE)	380.00	--	--	0.05
Total		100.00	100.00	100.05
Calculated composition, %				
CP (N × 6.25)	--	18.01	17.71	17.71
Crude fiber	--	3.50	3.50	3.50
Crude fat	--	6.77	5.60	5.60
ME, kcal/kg	--	3,200	3,135	3,135
Dig. Met	--	0.38	0.37	0.37
Dig. Met+Cys	--	0.60	0.59	0.59
Dig. Lys	--	1.00	0.98	0.98
Dig. Thr	--	0.67	0.65	0.65
Dig. Trp	--	0.18	0.17	0.17
Ca	--	0.75	0.74	0.74
P, available	--	0.35	0.34	0.34
Na	--	0.18	0.18	0.18
Cl	--	0.37	0.37	0.37
Cost/kg diet, PhP	--	21.88	21.32	21.50

[1]The vitamin premix provided the following quantities of vitamins per kg of complete diet: vit. A, 15,000 IU; vit. D_3, 2,700 IU; vit. E, 60 mg; vit. K_3, 2.7 mg; vit. B_1, 2.7 mg; vit. B_2, 6.6 mg; vit. B_6, 4.2 mg; vit. B_{12}, 0.03 mg; panthothenic acid, 21 mg; niacin, 45 mg; folic acid, 3 mg; and biotin, 0.30 mg.
[2]The mineral premix provided the following quantities of minerals per kg of complete diet: iron, 75 mg, manganese, 15 mg, zinc, 75 mg, copper, 4.5 mg, iodine, 0.105 mg, selenium, 0.054 mg, cobalt, 0.30 mg.

Table 2. Ingredient and nutrient composition (as-fed basis) of experimental diets fed during the grower phase (d 31 to 60)

Item	Price/kg (PhP)	Positive Control (PC)	Negative Control (NC)	NC + NSPE
Ingredient, %				
Yellow corn	14.80	57.17	59.28	59.28
Soybean meal, US	35.00	14.60	13.70	13.70
Rice bran D1	11.50	10.00	10.00	10.00
Copra meal	9.50	5.00	5.00	5.00
DDGS, corn	22.00	5.00	5.00	5.00
Molasses	18.00	3.00	3.00	3.00
Coconut oil	46.00	1.47	0.24	0.24
Monodicalcium phosphate	35.00	1.13	1.14	1.14
Limestone	1.60	1.13	1.13	1.13
L-lysine	115.00	0.51	0.52	0.52
L-threonine	160.00	0.21	0.21	0.21
DL-methionine	210.00	0.15	0.15	0.15
L-tryptophan	1,200.00	0.05	0.05	0.05
Salt	6.00	0.36	0.36	0.36
Vitamin premix[1]	1,150.00	0.03	0.03	0.03
Mineral premix[2]	102.00	0.06	0.06	0.06
Toxin binder	320.00	0.05	0.05	0.05
Copper sulfate	128.00	0.05	0.05	0.05
Ethoxyquin	250.00	0.02	0.02	0.02
NSP enzyme (NSPE)	380.00	--	--	0.05
Total		100.00	100.00	100.05
Calculated composition, %				
CP (N × 6.25)	--	15.99	15.74	15.74
Crude fiber	--	3.74	3.76	3.76
Crude fat	--	6.64	5.48	5.48
ME, kcal/kg	--	3,150	3,085	3,085
Dig. Met	--	0.35	0.34	0.34
Dig. Met+Cys	--	0.54	0.53	0.53
Dig. Lys	--	0.90	0.88	0.88
Dig. Thr	--	0.60	0.59	0.59
Dig. Trp	--	0.16	0.16	0.16
Ca	--	0.70	0.70	0.70
P, available	--	0.35	0.35	0.35
Na	--	0.18	0.18	0.18
Cl	--	0.39	0.39	0.39
Cost/kg diet, PhP	--	20.48	19.96	20.14

[1]The vitamin premix provided the following quantities of vitamins per kg of complete diet: vit. A, 15,000 IU; vit. D_3, 2,700 IU; vit. E, 60 mg; vit. K_3, 2.7 mg; vit. B_1, 2.7 mg; vit. B_2, 6.6 mg; vit. B_6, 4.2 mg; vit. B_{12}, 0.03 mg; panthothenic acid, 21 mg; niacin, 45 mg; folic acid, 3 mg; and biotin, 0.30 mg.

[2]The mineral premix provided the following quantities of minerals per kg of complete diet: iron, 75 mg, manganese, 15 mg, zinc, 75 mg, copper, 4.5 mg, iodine, 0.105 mg, selenium, 0.054 mg, cobalt, 0.30 mg.

Table 3. Ingredient and nutrient composition (as-fed basis) of experimental diets fed during the finisher phase (d 61 to 82)

Item	Price/kg (PhP)	Positive Control (PC)	Negative Control (NC)	NC + NSPE
Yellow corn	14.80	52.58	54.42	54.42
Soybean meal, US	35.00	7.70	7.00	7.00
Rice bran D1	11.50	15.00	15.00	15.00
Copra meal	9.50	10.00	10.00	10.00
DDGS, corn	22.00	5.00	5.00	5.00
Molasses	18.00	5.00	5.00	5.00
Coconut oil	46.00	1.20	--	--
Monodicalcium phosphate	35.00	0.85	0.86	0.86
Limestone	1.60	1.24	1.24	1.24
L-lysine	115.00	0.51	0.51	0.51
L-threonine	160.00	0.18	0.18	0.18
DL-methionine	210.00	0.12	0.12	0.12
L-tryptophan	1,200.00	0.05	0.05	0.05
Salt	6.00	0.35	0.40	0.40
Vitamin premix[1]	1,150.00	0.03	0.03	0.03
Mineral premix[2]	102.00	0.06	0.06	0.06
Toxin binder	320.00	0.05	0.05	0.05
Copper sulfate	128.00	0.05	0.05	0.05
Ethoxyquin	250.00	0.02	0.02	0.02
NSP enzyme (NSPE)	380.00	--	--	0.05
Total		100.00	100.00	100.05
Calculated composition, %				
CP (N × 6.25)	--	13.99	13.82	13.82
Crude fiber	--	4.39	4.41	4.41
Crude fat	--	7.52	6.38	6.38
ME, kcal/kg	--	3,100	3,035	3,035
Dig. Met	--	0.29	0.28	0.28
Dig. Met+Cys	--	0.45	0.44	0.44
Dig. Lys	--	0.75	0.74	0.74
Dig. Thr	--	0.50	0.49	0.49
Dig. Trp	--	0.14	0.13	0.13
Ca	--	0.70	0.70	0.70
P, available	--	0.30	0.30	0.30
Na	--	0.18	0.19	0.19
Cl	--	0.41	0.44	0.44
Cost/kg diet, PhP	--	18.48	17.98	18.16

[1]The vitamin premix provided the following quantities of vitamins per kg of complete diet: vit. A, 15,000 IU; vit. D_3, 2,700 IU; vit. E, 60 mg; vit. K_3, 2.7 mg; vit. B_1, 2.7 mg; vit. B_2, 6.6 mg; vit. B_6, 4.2 mg; vit. B_{12}, 0.03 mg; panthothenic acid, 21 mg; niacin, 45 mg; folic acid, 3 mg; and biotin, 0.30 mg.
[2]The mineral premix provided the following quantities of minerals per kg of complete diet: iron, 75 mg, manganese, 15 mg, zinc, 75 mg, copper, 4.5 mg, iodine, 0.105 mg, selenium, 0.054 mg, cobalt, 0.30 mg.

The NSPE used is a commercial preparation (Rovabio Excel AP, Adisseo, France) produced from fermentation of non-genetically modified *Penicilium funiculosum*. It contains 19 compatible enzyme activities working in synergy on a broad range of feedstuffs and species. It was added to the diet at the rate of 50 g/100 kg after premixing it with about 1 kg of soybean meal (part of the weighed amount for the diet mixed) as recommended by the manufacturer. The diets were mixed on a weekly basis using an electrically operated mixer. All diets were in mash form.

Data Collection

Pigs were weighed individually at d 0 (start of the experiment), 31, 60, and 82 to calculate for periodic and overall ADG. Total feed offered and feed refusal at the end of each phase was recorded for each pen to calculate for periodic and overall ADFI. By dividing ADFI by the ADG, F:G was calculated. Four pigs from each treatment were randomly selected for carcass evaluation. Pigs were fasted for 12 h when they reached 90 kg. After fasting, each pig was weighed and slaughtered following the procedures of Ibarra (1983) and carcass characteristics were determined. The mean cost per kg gain was computed for each feeding period. This was done by multiplying the ADFI by the cost per kg of diet.

Statistical Analysis

Data were analyzed using ANOVA of SAS (SAS Inst. Inc., Cary, NC). The least-significant difference (LSD) test was used to determine significant differences between treatment means at P = 0.05.

RESULTS AND DISCUSSION

Effects on Growth Performance

In the starter phase (d 0 to 31), there were no differences in growth performance between pigs fed the control diets (Table 4). However, pigs fed the NC+NSPE diet had greater (P=0.04) ADG and improved (P=0.03) F:G compared with pigs fed the PC and NC diets. There were no differences in growth performance among the treatments in the grower (d 31 to 60) and finisher phase (d 61 to 82). Overall (d 0 to 82), differences in ADG, F:G, and final weight of the pigs approached statistical significance. Growth performance of pigs fed the NC+NSPE diet were similar to those fed the PC diet but tended (P≤0.10) to have greater ADG and final weight and improved F:G compared with those fed the NC diet.

Results indicate that the addition of NSPE to the diet with reduced ME and DAA improved performance of pigs. This agrees with the findings of Cozannet *et al.* (2012) and Fang *et al.* (2007) who reported increased digestibility of nutrients and ADG in growing pigs fed diets with the NSPE used in the present work. The magnitude of response to the enzyme was greater in the starter phase which was 9.2% for ADG and 9.3% for F:G compared with the positive control.

Table 4. Growth performance of growing-finishing pigs fed diets with or without non-starch polysaccharides enzyme (NSPE)

Item	Treatment			LSD (P=0.05)	P-value
	Positive Control (PC)	Negative Control (NC)	NC + NSPE		
Starter (d 0 to 31)					
ADG, kg	0.76[b]	0.75[b]	0.83[a]	0.06	0.04
ADFI, kg	1.54	1.57	1.52	0.09	0.48
F:G	2.04[a]	2.10[a]	1.85[b]	0.19	0.03
Grower (d 31 to 60)					
ADG, kg	0.90	0.85	0.91	0.13	0.52
ADFI, kg	2.24	2.17	2.14	0.14	0.34
F:G	2.49	2.58	2.35	0.32	0.40
Finisher (d 61 to 82)					
ADG, kg	0.86	0.83	0.87	0.07	0.49
ADFI, kg	2.46	2.45	2.49	0.10	0.72
F:G	2.86	2.97	2.87	0.27	0.64
Overall (d 0 to 82)					
ADG, kg	0.84	0.81	0.86	0.05	0.10
ADFI, kg	1.94	1.96	1.95	0.04	0.78
F:G	2.30	2.42	2.27	0.14	0.08
Pig weights, kg					
d 0	25.6	25.6	25.6	0.2	0.73
d 31	49.1	48.8	50.7	2.0	0.14
d 60	76.0	74.2	78.1	3.8	0.13
d 82	94.1	91.7	96.4	4.0	0.07

[1]A total of 54 growing barrows (Duroc-Pietrain x Landrace-Large White; initial BW of 25.6±1.6 kg) were used with 6 replications per treatment and 3 pigs per replicate pen.
[a,b]Within a row, means without a common superscript differ (P<0.05).

Results indicate that the addition of NSPE to the diet with reduced ME and DAA improved performance of pigs. This agrees with the findings of Cozannet *et al.* (2012) and Fang *et al.* (2007) who reported increased digestibility of nutrients and ADG in growing pigs fed diets with the NSPE used in the present work. The magnitude of response to the enzyme was greater in the starter phase which was 9.2% for ADG and 9.3% for F:G compared with the positive control.

The responses, however, cannot be fully explained by the release of ME and DAA in the diet associated with the degradation of NSP. This is due to the lack of differences in the growth performance of the positive and negative control pigs despite the reduction in ME and DAA concentration in the diet. Apparently, nutrient requirements of the pigs were not compromised with the level of reduction in ME (65 kcal/kg) and DAA (1.5%). Reports indicate that benefits of using exogenous enzymes may be limited when diets exceed animal nutrient requirements (Graham and Bedford, 2007; Pluske and Lindemann, 1998). With the fact that growth performance of the pigs were not compromised with reduced ME and DAA, some other factors may explain for the beneficial effects of NSPE. These may include effects on feed transit time, endogenous losses, or changes in gut microflora (Pluske and Lindemann, 1998; Kitchen, 1997). It was likely that effects in any of these factors could have markedly influence to the pig performance during the starter period when large responses of the pigs to the NSPE were observed.

Effects on Carcass Characteristics

There were no significant differences among the treatments in terms of carcass characteristics (Table 5). The lack of differences indicate that the reduction of 65 kcal ME/kg and 1.5% DAA in the diet nor NSPE inclusion to the diet did not influence any of the carcass parameters.

Table 5. Carcass characteristics of growing-finishing pigs fed diets with or without non-starch polysaccharides enzyme (NSPE)

Item	Treatment			LSD (*P*=0.05)	*P*-value
	Positive Control (PC)	Negative Control (NC)	NC + NSPE		
Carcass weight, kg	60.82	59.63	58.06	6.33	0.63
Dress yield, %	63.68	61.80	62.32	5.19	0.71
Carcass length,	80.25	81.12	80.38	3.18	0.80
Backfat thickness, cm	1.84	1.59	1.55	0.41	0.29
Carcass color score	3.00	2.75	2.75	0.75	0.70
Marbling	1.00	1.00	1.00	-	-
Loin eye area, cm^2	56.04	54.14	53.43	8.02	0.76

Diet Economics

Relative to pigs fed the positive control diet, pigs fed the NC+NSPE diet had lower (*P*<0.03) cost per kg of gain in the starter and grower phase, but no differences were observed in the finisher phase. Overall, cost per kg gain of pigs fed the NC+NSPE diet was lower (*P*=0.01) by PhP 3.57 per pig compared with the positive control pigs.

Table 6. Diet economics.

Item	Treatment			LSD (P=0.05)	P-value
	Positive Control (PC)	Negative Control (NC)	NC + NSPE		
Starter (d 0 to 31), PhP	44.64[a]	44.85[a]	39.70[b]	4.04	0.02
Grower (d 31 to 60), PhP	51.09[a]	51.83[a]	43.34[b]	6.07	0.03
Finisher (d 60 to 82), PhP	52.78	53.38	52.15	4.86	0.86
Overall (d 0 to 82), PhP	47.61[a]	48.42[a]	44.04[b]	2.82	0.01

[1]A total of 54 growing barrows (Duroc-Pietrain x Landrace-Large White; initial BW of 25.6±1.6 kg) were used with 6 replications per treatment and 3 pigs per replicate pen.
[a,b]Within a row, means without a common superscript differ (P<0.05).

The results indicate that there is an economic advantage of adding NSPE to a diet with reduced 65 kcal ME/kg and 1.5% DAA. Factors that contributed to this difference was the reduction in cost of the diet and the improvements in F:G due to the addition of the NSPE to the diet.

CONCLUSIONS

In conclusion, addition of NSPE to a diet with reduced ME of 65 kcal/kg and 1.5% DAA improved growth performance of growing-finishing pigs, particularly in the starter phase. The effect of the enzyme may partly be associated to compensating some amount of ME and DAA and other beneficial effects of the enzyme at the gut level that cannot be fully elucidated in the present study. The inclusion of the enzyme to a diet with reduced ME and DAA decreased cost per kg of gain due to lower cost of the diet and improved production performance.

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REFERENCES

Choct M. 2006. Enzymes for the feed industry: past, present and future. *World's Poultry Sci J* 62: 5-15.

Cozannet P, Preynat A, and Noblet J. 2012. Digestible energy values of feed ingredients with or without addition of enzymes complex in growing pigs. *J Anim Sci Suppl* 4: 209-211.

De Vries JW. 2004. Dietary fiber: The influence of definition on analysis and regulation. *J AOAC International* 87: 682-706.

Fang ZF, Peng J, Liu ZL and Liu YG. 2007. Responses of non-starch polysaccharide-degrading enzymes on digestibility and performance of growing pigs fed a diet based on corn, soya bean meal and Chinese double-low rapeseed meal. *J Anim Physiol Anim Nutr* 91: 361–368.

Graham H and Bedford M. 2007. Using enzymes to improve energy utilization in animal feeds. Proc. 15th Annual ASA-IM Southeast Asia Feed and Nutrition Workshop. Conrad, Bali. Indonesia.

Ibarra PI. 1983. Meat Processing for small and medium scale operation. University of the Philippines, Los Baños, Laguna.

Kitchen DI. 1997. Enzyme Applications in corn/soya diets fed to pigs. In: Biotechnology in the Feed Industry. *Proc. Alltech's 12th Annual Symposium* (Eds. T.P. Lyons and K. A. Jacques). Nottingham Univ. Press, Loughborough, Leichs, UK, pp. 317-326.

Pluske JR and Lindemann MD. 1998. Maximizing the response in pig and poultry diets containing vegetable proteins by enzyme supplementation. In: Biotechnology in the Feed Industry. *Proc. Alltech's 14th Annual Symposium* (Eds. T.P. Lyons and K. A. Jacques). Nottingham Univ. Press, Loughborough, Leichs, UK, pp. 375-392.

Walsh MC, Geraert PA, Maillard R, Kluess J and Lawlor PJ. 2012. The effect of non-starch hydrolyzing enzyme (Rovabio Excel) on feed intake and body condition of sows during lactation and on progeny growth performance. Accessed 15 May 2013. http://www.ncbi.nlm.nih.gov/pubmed/23031562.