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Replacement of soyabean meal by white lupin cv. Bardo seeds and the effectiveness of β-glucanase and xylanase in growing-finishing pig diets*

Marianna Flis[1], W. Sobotka[1] and Z. Zduńczyk[2]

[1] Institute of Animal and Feed Management,
Olsztyn University of Agriculture and Technology
Oczapowskiego 5, 10-718 Olsztyn, Poland
[2] Institute of Animal Reproduction and Food Research,
Division of Food Science, Polish Academy of Sciences
Tuwima 10, 10-718 Olsztyn, Poland

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ABSTRACT

The effect of white cv. Bardo lupin seeds on the fattening performance of 35 barrows weighing 24 to 96 kg was determined. In the first period of fattening (growing up to 65 kg) the proportion of lupin seeds in the diets was 0, 8 and 14%, in the second period (finishing) 0, 14 and 20%. The amounts of lupin used replaced 0, 30 and 50% of soyabean meal in the growing, and 0, 75 and 100% in the finishing diets. The effectiveness of an enzymatic preparation containing β-glucanase and xylanase supplementing diets with varying proportions of soyabean and lupin and barley (52-65%) was also studied. The digestibility of dietary nutrients, nitrogen balance, daily weight gain and feed utilization were estimated.

The addition of white lupin seeds, containing 0.067% DM alkaloids, instead of soyabean meal did not have an unfavourable effect on nutrient digestibilities or nitrogen retention. Daily weight gains and feed utilization in pigs fed mixtures with an 8% (growing) and then 14% (finishing) lupin were the same as in the control group receiving soyabean meal. The higher proportion of lupin in the diets, i.e. 14% in the growing and 20% in the finishing diet, significantly decreased the growth rate of the pigs and feed utilization.

The addition of the β-glucanase and xylanase preparation (0.1% Porzyme 9100) increased only the digestibility of N-free extractives in the diets for young pigs (about 55 kg) and in both periods of

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fattening increased daily nitrogen retention.The daily gains were higher (3.6%) and the feed utilization was better (4%) in pigs fed diets supplemented with enzyme preparation, but differences were not significant.

KEY WORDS: white lupin, barley, β-glucanase, xylanase, digestibility, growth, pigs

INTRODUCTION

White lupin seeds are an important source of protein in pig diets in many countries. It is assumed that the nutritive value of diets containing white lupin seeds is decreased by two groups of compounds: antinutrients, mainly quinolizidine alkaloids and nonstarch polysaccharides (NSP). Symptoms caused by elevated dietary alkaloids, also found when low-alkaloid varieties are fed, include vomiting, reduction of feed intake and growth rate of animals (Cheeke and Kelly, 1989; Hill and Pastuszewska 1993). Lupin NSP are digested only to a small degree in the small intestine of pigs (12-14%) (Gdala et al., 1997), but undergo bacterial fermentation in the large intestine. Bacterial degradation of NSP is accompanied by loss of energy with gases and fermentation heat, and the energy of the short chain fatty acids formed in this process is less suitable for pigs than the energy from sugars absorbed in the small intestine (Just et al., 1983). It seems that an unfavourable effect of lupin NSP on the energy value of diets can be expected when diets with a high barley content are fed, since this grain also has considerable levels of NSP (18-20% DM) (Bach Knudsen, 1997). About 50% of the total NSP of barley comprises β-glucans and arabinoxylans (Henry, 1985). For this reason adding a preparation containing β-glucanase and xylanase to barley diets can be reasonable.

Because of their high sensitivity to lupin alkaloids, only varieties with very low levels of these compounds can be used in the feeding of pigs. From the studies of King (1981), Donovan et al. (1993) and Zettl et al. (1995) it results that the optimum level of low alkaloid white lupin seeds (0.018-0.033% alkaloids) for pigs over 25 BW is 10-12%. In earlier studies we found (Flis et al., 1997) that it is possible to obtain good results in feeding young pigs using a higher proportion of seeds of new varieties of white lupin (20%) – these results were insignificantly worse than when soyabean meal was fed. Because of the small number of animals and short duration of that experiment, the results obtained in it required confirmation on a larger population over the whole fattening period and the use of seeds obtained from commercial plantations cultivating the new varieties. Seeds from commercial plantations may have higher alkaloid contents compared with small samples of seeds from experimental plant breeding stations.

The objective of this study was to determine the extent by which the newest white lupin variety, Bardo, can replace soyabean meal in the diets of growing-finishing pigs.

The effectiveness of an enzyme β-glucanase and xylanase preparation added to barley-wheat, soyabean and lupin diets for fattening pigs was also determined.

MATERIAL AND METHODS

Animals and diets

The experiment was carried out on 35 barrows (Polish Large White x Duroc), from about 24 to 96 kg body weight, housed individually and fed according to Nutrient Requirements of Pigs (1993). In two periods of fattening (up to 65 and over 65 kg BW) five isonitrogenous mixtures were used: a control soyabean diet (C), a feed with a lower lupin content (LL), a diet with a higher lupin content (HL), a control diet with the addition of enzymes (C+E) and the diet with the higher lupin content and enzyme preparation (HL+E). In the LL diet, 30 and 75% of soyabean meal was replaced by lupin, in the HL diets, 50 and 100%, respectively, in the growing and finishing diets. The enzyme preparation, Porzyme 9100, added in an amount of 0.1% of the diet, contained (according to the manufacturer, Finnfeeds International LTD), 400 U/g β-glucanase and 400 U/g xylanase. The composition of diets are given in Table 1. The feed was given twice daily moistened, and the animals had free access to water.

The experiment was conducted in two replicates. In the first (A) the feeds were given to 3 barrows per group, in the second (B), to 4. In both replicates, the protein feeds were from the same lot. Lupin seeds, containing 0.067% DM alkaloids, from a commercial plantation that cooperates with plant breeding stations were used. The grains were from different lots but did not significantly differ in their chemical composition.

In replicate B, nutrient digestibilities were determined twice (total collection method). The nitrogen balance was determined first when the growing diet was used (55 kg BW), and a second time during the finishing period (80 kg BW). Faeces and urine were collected through 5 days. Two average 10% samples were taken from the daily faeces output. One sample was conserved with sulphuric acid, the other was dried. Dry matter, crude ash, ether extract and crude fibre were determined in the pooled samples from each animal. Urine was collected in containers with the addition of sulphuric acid (urinary pH under 2). In pooled samples of dairy urine for each animal nitrogen was determined.

Chemical analysis and calculation of nutritional value of the diets

The basic dietary nutrients of diets, faeces and urinary nitrogen were determined using conventional methods. The amino acid content of the diets was estimated from their content in the diet components, the content of alkaloids was based on their content determined in lupin seeds. The NSP content in diets was calculated on the basis of literature data (Gdala and Buraczewska, 1996; Bach Knudsen, 1997). Calcium and total phosphorous contents in the diets were calculated from data in Nutrient Requirements of Pigs (1993). The metabolic energy content in the diets was estimated using the Hoffman and Schiemann equation based on the chemical composition and digestibility coefficients determined experimentally, using the corrections for sugar and bacterially fermented structural polysaccharides (Nutrient Requirements of Pigs, 1993).

Statistical analysis

The experimental results were subjected to statistical analysis using the Duncan test, taking into account the bifactorial experimental design: groups and replicates.

RESULTS AND DISCUSSION

The average chemical composition and nutritive value of the diets, differed only slightly in replications A and B, are given in Tables 1 and 2.

The alkaloid content in the LL diets was 48 and 84 mg/kg, and in the HL diets, 84 and 120 mg/kg, in the first and second periods of fattening, respectively (Tables 1 and 2).

The digestibility coefficients of the nutrients and the results of the nitrogen balance are given in Table 3. Replacing soyabean meal in the diets for growing pigs with lupin seeds did not have a negative effect on the digestibility of the nutrients. Only a tendency towards decreasing the digestibility of crude protein as the amount of lupin in the diet increased was found (group LL and HL vs C). Also in the studies of Zettl et al. (1995) protein in diets containing 10 or 20% white lupin was less digestible than in the control soyabean diet. Crude protein, fibre and N-free extractives digestibility were similar in the finishing C, LL and HL diets. The digestibility coefficients of the ether extract rose with increasing level of lupin seeds in the diet, hence of the content of the ether extract in it. The digestibility of the ether extract of the HL diet (67.0%) was significantly higher than of the soyabean diet C (58.2%). The increase in apparent digestibility of ether extract of the diet as the content of white lupin increased was also observed in the experiment by Zetll et al. (1995). This was probably the result of two factors: the high digestibility of lupin fat (Roth-Meier and Kirchgessner, 1993; Flis et al., 1997) and the lower proportion of metabolic fat in the faeces of pigs fed diets with higher fat contents.

TABLE 1

Composition and nutritional value of diets for growing pig (24-65 kg BW)

Indices	Group				
	C[1]	LL	HL	C+E	HL+E
Ingredients, g/kg					
barley	562.0	544.4	524.3	561.0	529.3
wheat	200.0	200.0	200.0	200.0	200.0
soyabean meal (SBM)	205.0	142.0	102.0	205.0	102.0
white lupin	–	80.0	140.0	–	140.0
minerals[2]	23.0	23.0	23.0	23.0	23.0
mineral-vitamin premix	7.0	7.0	7.0	7.0	7.0
L-lysine,HCL 78%	1.5	1.9	1.9	1.5	1.9
DL-methionine, 99%	0.5	0.7	0.8	0.5	0.8
Fylax[3]	1.0	1.0	1.0	1.0	1.0
Porzyme 9100[4]	–	–	–	1.0	1.0
Chemical analysis, % air dry basis					
dry matter	88.51	88.42	88.85	88.79	88.72
crude ash	4.67	4.58	4.63	4.72	4.49
crude protein	17.48	17.46	17.27	17.48	17.34
ether extract	1.90	2.61	3.04	1.92	3.07
crude fibre	4.44	4.89	5.20	4.39	5.10
total alkaloids[5], mg/kg		48	84	–	84
NSP[6]	15.2	15.2	16.6	17.9	17.9
Nutritional value, g/kg					
lysine[5]	9.2	9.2	9.1	9.2	9.1
methionine[5]	3.0	3.0	3.0	3.0	3.0
threonine[5]	6.1	6.0	6.0	6.1	6.0
tryptofan[5]	2.1	1.9	1.8	2.1	1.8
Ca	7.1	7.1	7.0	7.1	7.0
P-total	5.6	5.6	5.5	5.6	5.5
metabolizable energy, MJ/kg	12.4	12.4	12.4	12.6	12.5
SBM subsitution by lupin, %	0	30	50	0	50

[1] C=control, LL=low lupin diet, HL=high lupin diet, C+ E=control+enzymes, HL+E= high lupin diet+enzymes

[2] limestone (1.1%)+bicalcium phosphate (0.9%) +salt (0.3%)

[3] preservation preparation

[4] enzyme preparation (β-glucanase 400 U/g, xylanase 400 U/g)

[5] value calculated according to analysed contents in feed ingredients

[6] value not determined but calculated according to literature data (Gdala and Buraczewska, 1996; Bach Knudsen,1997)

TABLE 2

Composition and nutritional value of diets for growing pig (65-95 kg BW)

Indices	Group				
	C[1]	LL	HL	C+E	HL+E
Ingredients, g/kg					
barley	648.1	602.5	572.5	647.1	571.5
wheat	200.0	200.0	200.0	200.0	200.0
soyabean meal (SBM)	125.0	30.0		125.0	–
white lupin	–	140.0	200.0	–	200.0
minerals[2]	17.0	17.0	17.0	17.0	17.0
mineral-vitamin premix	7.0	7.0	7.0	7.0	7.0
L-lysine (HCL 78%)	1.6	1.9	1.8	1.6	1.8
DL-methionine (99%)	0.3	0.6	0.7	0.3	0.7
Fylax[3]	1.0	1.0	1.0	1.0	1.0
Porzyme 9100[4]	–	–	–	1.0	1.0
Chemical analysis, % air dry basis					
dry matter	88.24	88.47	85.52	88.33	88.69
crude ash	3.85	3.69	3.55	3.91	3.66
crude protein	14.84	15.07	15.33	14.94	15.40
ether extract	1.94	3.17	3.62	1.92	3.54
crude fibre	4.15	4.64	5.21	4.24	5.16
total alkaloids[5], mg/kg	–	84	120	–	120
NSP[6]	15.0	17.7	18.9	15.0	18.9
Nutritional value, g/kg					
lysine[5]	7.6	7.6	7.7	7.6	7.7
methionine[5]	2.5	2.5	2.5	2.5	2.5
threonine[5]	5.2	5.2	5.2	5.2	5.2
tryptofan[5]	2.0	1.5	1.4	2.0	1.4
Ca	5.5	5.4	5.4	5.5	5.4
P-total	4.6	4.5	4.4	4.6	4.4
metabolizable energy, MJ/kg	12.5	12.5	12.7	12.6	12.6
SBM substitution by lupin, %	0	75	100	0	100

[1] C=control, LL=low lupin diet, HL=high lupin diet, C+E=control+enzymes, HL+E= high lupin diet+enzymes

[2] limestone (1.0% bicalcium phosphate (0.4%)+salt (0.3%)

[3] preservation preparation

[4] enzyme preparation (b-glucanase 400 U/g, xylanase 400 U/g)

[5] value calculated according to analysed contents in feed ingredients

[6] value not determined but calculated according to literature data (Gdala and Buraczewska, 1996; Bach Knudsen, 1997)

TABLE 3

Digestibility coefficients and N balance (repetition B)

	Group					
	C[1] 0-0[2]	LL 8-14	HL 14-20	C+E 0-0	HL+E 14-20	SE
	Growing period (55 kg BW)					
Digestibility coefficient, %	n=4	n=4	n=4	n=4	n=4	
crude protein	82.0	81.0	80.4	84.1	80.6	0.28
ether extract	56.1	56.1	57.2	61.2	60.7	0.80
crude fibre	40.3	43.9	42.3	45.4	43.8	1.11
N-free extractives	90.6	91.5	90.8	91.4	91.3	0.09
N balance						
intake, g/day	55.0	55.0	54.8	55.3	54.4	0.13
retained, g/day	19.0	21.5	18.1	20.8	20.2	0.41
N retained:N intake, %	34.4	39.0	33.1	37.6	37.2	0.72
	Finishing period (80 kg BW)					
Digestibility coefficient, %						
crude protein	80.7	80.3	80.4	82.7	80.9	0.21
ether extract	58.2^{B}	62.5^{AB}	67.0^{A}	63.8^{AB}	63.7^{AB}	0.45
crude fibre	37.4	38.3	43.7	38.6	43.2	0.66
N-free extractives	91.2	91.6	92.5	91.5	91.7	0.12
N balance						
intake, g/day	60.0	59.8	61.8	60.4	60.9	0.09
retained, g/day	19.8	20.4	18.5	20.3	20.0	0.50
N retained:N intake, %	33.1	34.1	29.9	33.5	32.9	0.82

[1] see under Table 1 and 2;

[2] share of the lupin seeds in growing-finishing pig diet; SE– standard error of the mean

means within a row with different superscripts are significantly different: a, b – $P<0.05$, A, B – $P<0.01$

Supplementing of β-glucanase and xylanase preparations to the control diet and lupin diets had only a slight effect during the growing period (Table 3). The digestibility of crude protein, ether extract and crude fibre decreased insignificantly, while that of N-free extractives declined significantly ($P<0.05$). During the finishing period no effects of enzyme additives on the digestibility of dietary components was found.

Literature data point to the differentiated effect of enzyme supplementation on the digestibility of nutrients of pig diets. In animals over 30 kg fed barley diets Thacker et al. (1992 a,b) and Baas and Thacker (1996) found that enzyme preparations in which β-glucanase predominated did not have a significant effect on the apparent digestibility of nutrients. Baas and Thacker (1996), however, found a tendency for higher digestibility of dry matter, crude protein (from 74.1 to 77.2 and 78.6%) and energy when Porzyme preparation containing β-glucanase (which retains a considerable part of its initial activity in the duodenum 60 and 240 min after feeding) was added. A significant rise in the intestinal digestibility of β-glucans and arabinoxylans and the apparent digestibility of barley crude protein and arabinoxylans after adding β-glucanase to the diets of older pigs (40 and 80 kg) was found by Graham et al. (1988).

Daily nitrogen retention during growing period equaled 21.5 g in the LL group, 18.1 g in the HL group and did not significantly differ from that in group C (19.0 g) (Table 3). In the finishing period too, daily nitrogen retention in pigs fed diets containing lupin did not differ significantly from nitrogen retention in pigs fed the control diet. The utilization of absorbed nitrogen equaled 34.4, 39.0 and 33.1% in the growing period (55 kg) and 33.1, 34.1 and 29.9% in the finishing period (80 kg), respectively in groups C, LL and HL, and did not differ significantly. A tendency towards decreasing daily nitrogen retention and utilization of absorbed nitrogen was seen in pigs receiving the diets with higher lupin contents (group HL vs C).

The addition of β-glucanase and xylanase to the barley-wheat diets caused an insignificant increase in daily nitrogen retention, by 2 g during the growing and 1 g during the finishing periods. During the finishing period the effect of adding enzymes on the retention and utilization of absorbed nitrogen was somewhat higher in the group fed the lupin containing diet (HL+E vs HL) than in the control diet (C+E vs C). The slightly higher, but statistically insignificant, daily retention of nitrogen in pigs receiving feed with β-glucanase and xylanase preparation may indicate point a higher crude protein digestibility of the diets in the small intestine.

The daily weight gains of pigs fed the LL diets (with the low lupin content) equaled 687 g and were the same as in the control group C (soyabean), 684 g. Feed intake per kilogram weight gain in group LL (3.07 kg) was similar to that in group C (3.11 kg) (Table 4).

The daily weight gains of pigs fed the diets with the higher lupin content (HL) were insignificantly lower during the growing period (594 g) than of the control group C. In the finishing period, when the proportion of lupin in the diet increased to 20%, daily weight gains in the HL group were significantly ($P<0.05$) lower than in group C. Also, during the whole fattening period, the daily weight gains of pigs fed the HL diet were significantly lower than in group C. In comparison with the controls, during the whole fattening period, the HL pigs consumed significantly more feed (3.31 vs 3.11 kg), metabolic energy (41.5 vs 38.6 MDI) and crude protein (541 vs 505 g) per kg weight gain.

The lower daily weight gain and worse feed utilization in pigs fed the diet with the higher lupin content (HL) can be attributed in part to the unfavourable effect of

TABLE 4

Average daily gain and feed conversion efficiency (repetition A+B)

	Group					SE
	C[1] 0-0[2]	LL 8-14	HL 14-20	C+E 0-0	HL+E 14-20	
Number of pigs	7	7	7	7	7	
Initial BW[3], kg	24.3	24.3	24.1	24.0	24.6	0.29
Final BW, kg	97.6	97.9	92.4	98.3	95.9	0.48
ADG[4], g day						
24-65	632^{abc}	645^{ab}	594^{cB}	656^{aA}	609^{bc}	10.01
65-95	771^{a}	757^{ab}	710^{bB}	789^{aA}	760^{ab}	6.51
24-95 kg	684^{ab}	687^{ab}	637^{cB}	705^{aA}	665^{bc}	7.71
Relative, %	100	100.4	93.1	103.1	97.2	
FCE[5],kg/kg						
24-65	2.80^{ab}	2.71^{b}	2.95^{a}	2.71^{b}	2.86^{ab}	0.02
65-95	3.54^{b}	3.62^{ab}	3.83^{aA}	3.45^{bB}	3.56^{b}	0.02
24-95 kg	3.11^{b}	3.07^{b}	3.31^{aA}	3.01^{bB}	3.16^{ab}	0.02
Relative, %	100	98.7	106.4	96.8	101.6	
ME:BWgain, MJ/kg						
24-65	34.7^{ab}	33.5^{b}	36.5^{a}	34.2^{ab}	35.6^{ab}	0.37
65-95	44.2^{b}	45.3^{b}	48.5^{aA}	43.5^{bB}	44.8^{b}	0.36
24-95 kg	38.6^{B}	38.3^{B}	41.5^{A}	38.0^{B}	39.5^{B}	0.33
CP[6]:BW gain, g/kg						
24-65	490	473	511	475	496	5.76
65-95	525^{bB}	545^{b}	586^{aA}	515^{bB}	548^{B}	5.21
24-95 kg	505^{b}	501^{bB}	541^{aA}	491^{bB}	518^{ab}	5.19

[1] see under Table 1;
[2] share of the lupin seeds in growing-finishing pig diets; SE – standard error of the mean
[3] body weight
[4] average daily gain
[5] feed conversion efficiency
[6] crude protein
means within a row with different superscripts are significantly different: a, b, c – $P<0.05$, A, B – $P<0.0$

alkaloids. Although the alkaloid content in the HL diet was not high (84 and 120 mg/kg, during growing and finishing period, respectively), similarly as the HL+E diet, it was unwillinghly consumed. In the study by Buraczewska et al. (1993) it was found that the level of white lupin alkaloids tolerated by young pigs (20-45 kg) was about 120 mg/kg. In our experiment, the HL diet contained this level of alkaloids during the finishing period (65-95 kg). However, in the studies of King (1981), a decline in the growth rate of pigs was seen even at a relatively low dietary alkaloid content (20.7% white lupin containing 0.018% alkaloids). It is also possible that the slightly higher content of nonstarch polysaccharides from the lupin in the HL diet than in the C diet (18.9 and 15.0%, respectively in the finishing diets) lowered the energy value of this diet, and in this way, in addition to alkaloids, also negatively affected animals performance.

The addition of the enzyme preparation both to the control diet (C+E) and to the diet with the higher lupin content (HL+E) did not significantly affect daily weight gain and feed utilization (Table 4). In considering the joint effects of the addition of enzymes, the tendency to increase gains (by 3.6%) and to decrease feed consumption (by 4.0%) per kg weight gain was found. The effect of β-glucanase and xylanase on weight gain and feed utilization in pigs weighing 24-95 kg was not significant, but was higher than in the study of Thacker et al. (1992 a,b) and Baas and Thacker (1996).

CONCLUSIONS

The results obtained in this study show that in pig feeding practice, when using feeds with a predominance of barley, white lupin cv. Bardo (0.067% DM alkaloids) can be used in amounts of 8% of the diet in the growing and 14% in the finishing periods. The addition of an enzyme preparation containing β-glucanase and xylanase (0.1% Porzyme 9100) to a barley-wheat diet containing soyabean meal or to a diet with a high level of white lupin insignificantly increased daily weight gain (by 3.6%) and feed utilization (by 4.0%).

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STRESZCZENIE

Zastąpienie poekstrakcyjnej śruty sojowej łubinem białym odmiany Bardo oraz efektywność preparatu β-glukanazy i ksylanazy w żywieniu tuczników

Badano wpływ udziału nasion łubinu białego odmiany Bardo na efekty tuczu 35 wieprzków od ok. 24 do 96 kg masy ciała. W pierwszym okresie tuczu (grower – do 65 kg) udział nasion łubinu w mieszankach wynosił 0, 8 i 14%, a w drugim (finisher) 0, 14 i 20%, zastępując nimi 0, 30 i 50% poekstrakcyjnej śruty sojowej w okresie grower oraz 0, 75 i 100% w okresie finisher. Określono również efektywność dodatku preparatu enzymatycznego z β-glukanazą i ksylanazą do diet z różnym udziałem poekstrakcyjnej śruty sojowej i łubinu oraz dużym udziałem jęczmienia (52-65%).

Oznaczono strawność składników pokarmowych diet, bilans azotu oraz dzienne przyrosty i wykorzystanie paszy.

Zastąpienie śrutą łubinu białego (0.067% s.m. alkaloidów) poekstrakcyjnej śruty sojowej nie wpłynęło ujemnie na strawność składników pokarmowych diet i retencję azotu. Dzienne przyrosty i wykorzystanie paszy u świń żywionych mieszankami z udziałem 8% (grower), a następnie 14% (finisher) łubinu były takie same jak w grupie kontrolnej. Większy udział łubinu w mieszankach, tj. 14% w grower i 20% w finisher istotnie zmniejszył tempo wzrostu świń i spowodował pogorszenie wykorzystania paszy.

Dodatek preparatu z β-glukanazą i ksylanazą (0.1% Porzyme 9100), oprócz zwiększenia strawności związków bezazotowych wyciągowych, nie wpłynął na strawność składników pokarmowych diet młodych świń (ok. 55 kg). W obu okresach tuczu spowodował natomiast zwiększenie (P>0.05) dziennej retencji azotu. Świnie otrzymujące dodatek enzymów miały większe (o 3.6%) dzienne przyrosty i lepiej (o 4.0%) wykorzystywały paszę, lecz różnice te nie były istotne.